

DYNAMIC
OCULAR TESTS

—
SHEARD

WW
300
S539d
1917

52310640R



NLM 05274016 8

NATIONAL LIBRARY OF MEDICINE

SURGEON GENERAL'S OFFICE
LIBRARY.

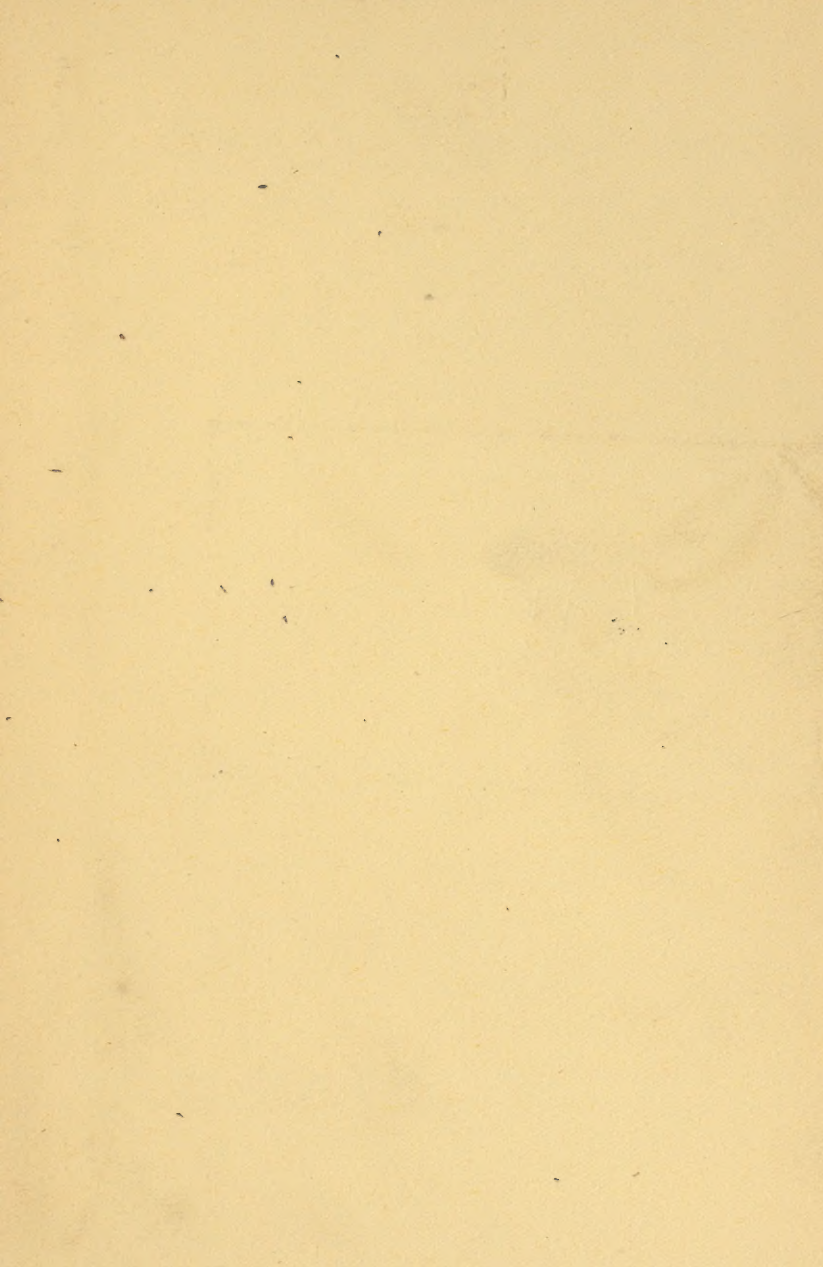
~~ANNE~~

Section -----

No. 113,
W. D. S. G. O.

No. 231181

2-513



DYNAMIC OCULAR TESTS

Being

A Compendium Dealing with Certain Phases of the Correlation of Accommodation and Convergence, together with Some Original Objective Methods of Investigating the Range and Amplitude of Accommodation both Monocularly and as Associated in Binocular Single Vision.

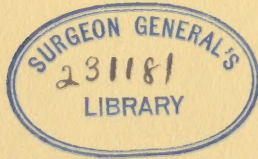
BY

CHARLES SHEARD, Ph. D.

Director and Professor of Applied Optics, the Ohio State University:
Collaborator in and Author of the Section on Physiologic Optics, The American Encyclopedia of Ophthalmology: Author of Cylindrical Lenses, Dynamic Skiametry and various Physical and Physiologic Optical Researches in The Ophthalmic Record, The Physical Review and The Philosophical Magazine.



THE LAWRENCE PRESS CO., COLUMBUS, OHIO



WW
300
S539d
1917
C.1

Film 9583, Item 1

Dedicated to all men
scientifically interested
in ocular refraction.

Copyright 1917

By Charles Sheard

TABLE OF CONTENTS.

CHAPTER.	PAGE.
I. THE OUTLINE OF AN EYE EXAMINATION WITH SPECIAL REFERENCE TO CERTAIN DYNAMIC TESTS UPON THE EXTRA-OCULAR MUSCLES	7
II. VARIOUS SUBJECTIVE DYNAMIC METHODS OF INVESTIGATING CONVERGENCE AS ASSOCIATED WITH ACCOMMODATION, FUSIONAL CONVERGENCE, AND THEIR IMPORTANCE	58
III. A RESUME OF PRESENT DAY METHODS OF INVESTIGATING THE ACCOMMODATIVE RANGE AND AMPLITUDE	86
IV. A RESUME OF METHODS OF DETERMINING THE RELATIVE RANGE AND AMPLITUDE OF ACCOMMODATION AND CONVERGENCE	95
V. AN OBJECTIVE METHOD OF DETERMINING THE MONOCULAR AMPLITUDE AND RANGE OF ACCOMMODATION.	104
VI. AN OBJECTIVE METHOD OF DETERMINING THE BINOCULAR RANGE AND AMPLITUDE OF ACCOMMODATION AND THE EFFECTS WHICH LATERAL IMBALANCES HAVE UPON THE SAME	115
VII. THE PRINCIPLES AND METHODS OF DYNAMIC SKI-AMETRY	124
BOOKS FOR STUDY AND REFERENCE.....	139

BY WAY OF INTRODUCTION.

When a writer assigns himself the delightful task of preparing a brochure upon some central theme he is invariably confronted with the problem of what to omit. There has been such a development in ophthalmological and optical science within the past twenty years, particularly along lines pertaining to investigations upon the ocular muscles, that one can hope, in a compendium of this character, to call attention only to some of the most important aspects of the subject.

We have, up to the present time, insofar as the writer knows, been possessed of no objective methods of investigating the accommodative resources. One of the principal purposes of this rubric is to place before practitioners upon the eye some original and very simple methods dealing with objective examinations upon the accommodation and to point out their importance. Very naturally monocular tests lead into ways and means of making binocular investigations upon such functions; we are, therefore, including a brief presentation of some of the valuable subjective tests which should be made upon accommodation as associated with convergence, and fusion convergence, as well as the objective tests peculiar to dynamic ski-ametry.

No single method of examining the ocular resources can or should be considered a *sine qua non*. That which one method fails to reveal and disclose may be made apparent through another. Hence, it behooves all practitioners to engage in *dynamic* as well as

static ocular tests. Data upon ocular functions and their correlation should be obtained as a matter of routine examination ; we cannot hope to scientifically solve an intricate ocular problem without the premises from which to draw our conclusions.

The topics which are presented within these pages, together with many discussions germane thereto, are receiving detailed attention in the author's series of articles on "*Dynamic Skiametry and Other Dynamic Methods for the Determination of the Proper Coordination of Accommodation and Convergence and the Conservation of the Visual Functions*" now appearing in the Keystone Magazine (Philadelphia) of Optics. These, when completed, will be published in book form by the Keystone Company.

We are hoping that we shall find the time and have the strength to prepare from year to year similar brochures to the one now being presented to you. If all is well we shall next greet you with a small volume on "Prisms—When and When Not to Prescribe Them."

We hope the reader will pardon any "sins of omission or commission." These paragraphs have been penned during the leisure moments of a rather busy daily life.

And again, if you disagree with any or all of the views herein presented, so much the better, if such disagreement is not only iconoclastic but constructive.

Written from my study and office.

365 W. 10th Ave.,

Columbus, Ohio.

June, 1917.

CHAPTER I.

The Routine of an Eye Examination With Special Reference to Certain Dynamic Tests Upon The Extra-Ocular Muscles.

No two men would, in general, build exactly the same kind of a house. Yet, in the last analysis, each must have a definite plan of procedure and would normally pass from the cellar to the roof, fitting each part into symmetry and usefulness to form the whole. Fundamentally, there must be *order*; it has not been granted man to bring order out of chaos at a moment's notice or without a study of the problem involved and a coordination of the correlated parts. The writer hopes, therefore, that the reader of experience will pardon these few oncoming paragraphs in which attention is called to (1) the necessity of orderliness of arrangement as well as cleanliness of office and convenience and ease of operation in making ocular tests, and (2) the necessity for a complete record of the results of the various tests made.

Nothing disgusts or chagrins me more than to enter an office which is untidy, filled with superfluous material or so ordered as to actually if not purposely attempt to throw over me some sort of an impression as to the eruditeness of the occupant. Simplicity and orderliness should be written over everything—including the practitioner.

Full and accurate data should be preserved in every case examined. Paper and cardboard are relatively cheap and afford a means of making a permanent

record of one's investigations; man's memory is short and his brains are too valuable to be used as an encyclopedia of specific facts in any case.

The writer uses a plain white card, 5 x 8 inches in size. This is large enough to prevent the very evident psychological reaction caused by too small a card and yet small enough to be conveniently handled and filed away. We have never believed in cards printed in various sub-headings for the reason that no two cases ever call for the same amount of recorded material upon any point. In a word, plenty of space is conducive to an ample record of data.

As a general rule we follow the subjoined order of procedure, modifying any tests or omitting any which we deem best. We believe, however, that it is unwise to assume anything in any scientific investigation, least of all in ministering to the most precious faculty of vision, and that as a general rule *all static and dynamic tests* should be employed.

OUTLINE OF THE ROUTINE.

1. History.
2. Ophthalmoscopic and External Eye Examination.
3. Ophthalmometric Examination.
4. Static Retinoscopic Investigations.
5. Dynamic Skiametric Tests.
6. Monocular and Binocular Objective Tests Upon the Amplitude and Range of Accommodation.
7. Subjective Acuity Tests.
8. Comparison Tests as to Equality of Acuity at Distance.
9. Binocular and Monocular Tonicity Tests.

10. Monocular Test of the Oblique Muscles.
11. Duction Tests of the Recti and Oblique Muscles.
12. Version Tests.
13. Accommodative Convergence Tests at the Reading Point.
14. Tests for Cyclophoria and Hyperphoric Conditions at the Reading Point.
15. Subjective Monocular and Binocular Near-points.
16. Comparison Tests as to Equality of Accommodative Amplitude.
17. Monocular Tests Upon Amplitude of Accommodation (using Concave Lenses, the patient reading No. 2 Jaeger type at thirteen inches.)
18. Fusional Reserve Convergence at the Reading Point.

HISTORY.

The full data as to name, age, occupation and so forth should be initially recorded. The question of occupation is most important since many vital points of refractive correction are thereby emphasized, particularly when the occupation is one demanding chiefly distance or near vision as the case may be and in presbyopia. The usual series of questions put to the patient should include inquiries upon (a) difficulties in distant or near work, (b) headaches and their location, (c) ocular fatigue, (d) drowsiness, nausea or dizziness, (e) ability to change readily from distant to near seeing and vice versa, (f) diplopia, either at distance or near, (g) sensitiveness to light, both natural and artificial, (h) diseases, particularly diphtheria, scarlet

fever, recent condition of measles, nervous exhaustion or anemia, conditions of throat, ears, nose and teeth, since these are most important factors in the etiology of restricted or weakened accommodation—a condition, by the way, very frequently encountered—as well as in deficient muscular innervations.

OPHTHALMOSCOPIC AND BLOOD PRESSURE EXAMINATIONS.

No case should ever fail of an ophthalmoscopic and external eye examination. To the refractionist who is a non-medical practitioner this is absolutely essential as the first step in an examination, since abnormal conditions should not in general receive optical treatment until after the case has been referred back by the medical practitioner. All pathologic conditions should be immediately referred to the family physician or otherwise designated practitioner of medicine. If the case is one demanding refractive as well as medical treatment the writer sees no reason why all the ocular comfort possible should not be rendered the patient, provided he make the reference referred to and provided the results of his investigations will not be simply of a temporary nature to be ultimately largely modified after proper medical treatment.

Blood pressure tests have been extremely valuable in ocular work, especially in cases of very high or low pressure. They often serve as corroborative evidence of ophthalmoscopic examinations which evidence retinal hyperesthesia, constricted papilla, tortuous veins, depleted arterial circulation. In fact such blood pressure tests may be more prognostic than diagnostic and serve as a means, taken with the patient's history,

of discovering various impending conditions before they are clearly written upon the retina. *E. G. Wiseman* has written a most valuable treatise on "Blood Pressure in Ocular Work," which should find a place in the study of every refractionist.

OPHTHALMOMETRIC EXAMINATION.

While the findings as obtained by the ophthalmometer upon the amount and axis of the astigmatism are not in general of sufficient accuracy to enable us to prescribe directly therefrom, these findings are, nevertheless, most valuable. For the cornea is the only portion of the refractive apparatus which is not subject to change during an examination. The location of the principal meridians and the refractive differences between them serve, when the usual allowance is made for the presence of approximately half a diopter of physiologic astigmatism against the rule, as a valuable initial determination of the amount and the axis of the probable astigmatism and aid materially in retinoscopic determinations. Many reasons can be assigned as to why ophthalmometric, retinoscopic and subjective findings do not agree *in toto* in the determination of astigmatism. Disagreements in such findings in reality furnish the examiner with differential tests. The normal cornea may be taken as having a radius of curvature of about 7.5 mms. or 45 diopters power. If both pointers on the instrument or the measurement of both meridians indicate radii of curvature greater than 7.5 mms. plus cylinders are in general indicated with the axis in such a position as to tend to make both meridians of equal power, this power being the highest obtainable. If both pointers on the instru-

ment indicate radii of curvature less than 7.5 mms. minus cylinders may be safely assumed as indicated to bring the equality of refractive power as nearly a minimum value as possible. A corneal astigmatism may be neutralized by a physiologic astigmatism of the posterior surface of the cornea, by a tilting of the lens or lack of alignment of the ocular refractive parts or by accommodative astigmatism.

The practitioner must be on his guard that cylinders, incorrect in character and axis, are not prescribed. We refer to a prescription such as — 0.50 cyl. ax. 180 whereas + 0.50 ax. 90. should have been prescribed and was really demanded. Necessarily, in cases of compound corrections, such reversal of character and axis of the cylinder may legitimately occur and the only question can then be that relative to under-or over-correction spherically; the question of the spherical element is, after all, one of the most vital points in such cases as the following:

Case 1. A young lady, aet. twenty-five years, came in complaining of extreme nausea, inability to study or concentrate or do anything which in anywise demanded the use of her eyes for an hour. She was wearing lenses, O. U. —.75 cyl. ax. 180, prescribed about a year previously under a cycloplegic. The ophthalmometric determinations showed in each eye the following: horizontal meridian (180°) 43.75 D, vertical meridian 45 D. One would, therefore, presumably have looked for a correction involving +0.75 cyl. ax. 90 or its equivalent in transposed form should a spherical element enter. Static retinoscopy, after some fifteen minutes' inaction of the eyes under fogging lenses, and

the subjective determinations disclosed practically the same findings as she was then wearing. Dynamic skiametry at 13 inches indicated O. U. $+0.5$ D. S. $\ominus +0.75$ cyl. ax. 90 or in transposed form O. U. $+1.25$ D. S. $\ominus -.75$ cyl. ax. 180. The tests upon convergence as associated with the accommodation at the reading point, fusion being passive, evidenced some 6° esophoria. The total amplitude of accommodation was not in excess of 6 D, wearing the dynamically determined correction. The evidence was clear, therefore, that her accommodative needs were not being adequately met at the time she consulted us; as a result we judged it wise to give her O. U. $+0.75$ cyl. ax. 90 (equivalent, of course, to $+0.75$ D. S. $\ominus -.75$ cyl. ax. 180) for near work at first, but to be ultimately worn, if possible, for all distances. This was done, soon affording permanent relief and satisfaction. The ophthalmometric findings were to my mind a valuable aid in the solution of this ocular problem, demanding not only an astigmatic correction but also accommodative assistance. Hence the static retinoscopic and subjective tests must be held in abeyance in view of certain ophthalmometric findings and in the face of dynamic skiametric tests, dynamic tests upon the accommodation and various dynamic tests upon the correlation of accommodation and convergence.

The ophthalmometric determinations are of considerable value also in cases of oblique astigmatism and in cases of cyclophoria when binocular single vision is attempted. Cases arise in which static retinoscopic and subjective tests conducted at twenty feet disclose the axis of astigmatism at 90° , for example, when the

ophthalmometer shows the axis at slightly oblique positions, such as 80° or 100° . The writer believes that when an eye, not under the influence of a cycloplegic, looks down the barrel of the ophthalmometer it rather definitely fixes monocularly the end of the telescopic tube and that, while its mate may be under cover, there is a considerable amount of binocular activity and convergence under conditions as ordinarily found. Hence, it often occurs that ophthalmometric axes in cases of oblique astigmatism agree better with dynamic skiametric or binocular findings than with monocular findings obtained by either static retinoscopic or subjective methods. This would indicate that differences between (a) ophthalmometric and (b) retinoscopic or subjective monocular findings as to the position of the axis of correcting cylinders may be attributed, in part at least, to the fact that in the first named set of findings binocular functions are more active than in the latter named tests.

Case 2. We cite at this point the case of a woman forty-five years of age who had suffered all her life from ocular discomfort and who had not been able to do much if any near work. Static retinoscopy disclosed O. U. $+0.5$ D. S. $\ominus +1.25$ cyl. ax. 90 and subjectively these lenses gave normal visual acuity. She was wearing a binocular distance correction of $+0.62$ D. S. $\ominus +1.12$ cyl. ax. 90, which, in the light of all the acuity and muscular poise tests at twenty feet, seemed satisfactory. Dynamic skiametry with fixation and observation at thirteen inches indicated O. D. $+2.5$ D. S. $\ominus +1.25$ cyl. ax. 75° — 65° and O. S. $\ominus +2.5$ D. S. $\ominus +1.25$ cyl. ax. 105° — 115° . The

ophthalmometer findings showed the axis at 80 and 100 degrees respectively; a case, by the way, affording evidence of the fact that the ophthalmometric findings, in which of course only corneal astigmatism is disclosed, agreed better with the dynamic than the static findings as to the position of the correcting cylinders. Thus, in spite of the monocular occlusion, an eye fixing the end of the telescope (unless under the influence of a complete cycloplegia) will assume a condition of muscular poise and balance approximating at least the conditions existing under binocular usage. The tests at the reading point in the case under discussion were, therefore, made by initially inserting the sphere for reading as dynamically determined. With such assistance some of Snellen No. 3 ($V=1$ D. S.) could be made out. The insertion of the $+1.25$ cyl. ax. 90 enabled still smaller type to be read, but not with ease or clearness; an increase or decrease of spherical element did not benefit conditions. The cylinder was turned into the 75° position, when No. 2 Jaeger type ($V=.5$ D. S.) was read with ease and comfort and evidence afforded of a considerable range of reading accommodation. A similar test upon the left eye exhibited superior acuity results with the cylinder at position 105° . The results binocularly with the cylinders at the oblique axes were infinitely better than with the cylinders in the positions statically determined and as statically demanded in the distance correction. With these corrections before the eyes, a test was made for the cyclophoric imbalances by the use of the double Maddox prism and a line of test type. (See Figures 23 and 25, Chapter II.) A fair degree of

minus cyclophoria was evidenced at the reading point and practically none at distance; in the latter tests no corrections were inserted before the eyes. Following the *Steele* rules as laid down in *Savage's* "Ophthalmic Neuro-Myology" (see also *Savage's* "Ophthalmic Myology," page 406), this woman was given for reading O. D. +2.25 D. S. $\subset$ +1.25 cyl. ax. 75 and O. S. +2.25 D. S. $\subset$ +1.25 cyl. ax. 105.

Such a case as this, to be sure, is not of common occurrence. As to the etiology of the rotation of the astigmatic planes or torsion of the vertical meridional planes nasally we can only conjecture. As *Savage* says: "A too high attachment of the interni or too low attachment of the externi would cause a minus cyclophoria, while a too low attachment of the interni or too high attachment of the externi would cause a plus cyclophoria. When there is a normal attachment of the interni, there can result from their action no cyclophoria." In the case in hand, we may believe from the evidence afforded that the interni were attached too high (or the externi too low), and that in the act of converging there was caused a torsion of the eyeballs about their anteroposterior axis turning the upper portions of the vertical meridians nasally in each case and therefore throwing upon the inferior obliques a burden which they could not bear. The superior obliques would correspondingly be relieved from normal action.

This account of these interesting ocular conditions is inserted at this point to call attention to the possible effects which such muscular conditions, because of their effects upon the poise of the eyeball and the posi-

tions of the vertical and horizontal meridians, may have upon the visual tests conducted at the reading point and upon the accommodative resources as apparently or subjectively exhibited. Such a case as this as well as many others, exhibiting apparently subnormal or depleted accommodation, as judged by the subject's ability to read fine print, emphasizes the great need of some satisfactory objective method of determining the amount of accommodation possessed by a patient. The writer has developed such a method and, while it may not be all that might be desired, it will be disclosed in later paragraphs and will be found most serviceable.

STATIC RETINOSCOPIC TESTS.

It is not our purpose to go into the details of the methods and practices of static retinoscopy: these may be obtained from any of the several standard treatises upon this subject. We do desire, however, to call attention to some of the factors which may cause disagreement between such findings and the results of subjective tests.

(A) *Ciliary Relaxation. Fixation Definite but Passive.* If the patient looks vaguely into space without the assistance of some definite and partially visible fixation point, his gaze is more than likely to be both uncertain in direction as well as position. To insure this definiteness of fixation the one-hundred-foot letters may be turned up in the chart and the patient told to keep his attention fixed upon them. The great criterion in static methods is ciliary relaxation. Hence monocular fixation must be definite but passive. The writer has also found it advantageous in cases of

hyperopia, in suppressing accommodation, to turn up in the lens battery of the optometer or insert in the trial frame sufficient lens power to considerably over-correct and cause opposite retinoscopic motion to that initially discovered when only the working lens is present. In cases of myopia such a method is not generally necessary since the working lenses are sufficient for this purpose. The procedure is to then slowly reduce lenticular power until the maximum plus and minimum minus just before reversal of shadow occurs is reached.

(B) *Retinal Sensitiveness*. Retinæ unduly sensitive to light may cause, under the influence of light thrown from the observer's mirror into the eye, a temporary irritation that will produce a spasm of the ciliary. Such reflex actions may be induced to relax by dimming the source of light used in skiametric work. The self-luminous instrument is generally superior to the non-luminous mirror in this particular. One may be forced to make his findings *ad interim* by flashing the light on and off the eye under examination.

(C) *Irregular and Peripheral Refraction*. The cornea and other refractive media may not be properly centered or regularly curved. Hence exact neutralization of the skiascopic shadow may be impossible or difficult, (see the section on "Scissor Movements.") The "visual zone" or the portion of the pupil surrounding the visual axis should be regarded in retinoscopic testing. Very frequently hyperopic cases will arise in which, due to large pupils with the existence of positive aberration, a shadow will be apparently neutralized or even reversed when the

motion at the center of the pupil will still be "with", or hyperopic.

(D) *Macular vs. Non-Macular Refraction.* In static retinoscopic tests as usually conducted, the patient's gaze as to his right eye is directed over the operator's right shoulder and over his left for the left eye. The portion of the retina thus made conjugate to the point passively fixed, due allowance being made for the working lens, is not the same as is made conjugate to the observer at this working distance. In other words, the refraction is not determined along the *visual axis*. We cannot assume a uniformly curved or spherical retinal surface; the fovea is known to be a slight depression in the macular area; hence objective findings may differ considerably when the light spot upon the retina falls at or remote from the fovea. The vital point is, therefore, that the skiascopic findings are not ordinarily made along the visual axis and hence many irregularities, due to obliquity of lenses, non-macular conjugate point and so forth may arise and disagreements between objective and subjective methods result because of lack of proper precaution in knowing the conditions under which each is carried out.

EBERHARDT'S MACULAR REFLECTOSCOPE.

John C. Eberhardt has devised a simple and ingenious method of testing very close to the fovea centralis and the writer is pleased to say from experience that he has found it most serviceable. The "macular reflectoscope" as constructed by the inventor consists of a stand placed, say, forty inches from the patient

and carries two mirrors. The device is diagrammatically shown as a horizontal cross-sectional cut in Figure 2.

The macular reflectoscope is represented at *D* and consists of two parallel, plain mirrors, *L* and *N*, so placed before the eye of the person being examined as to enable an illuminated eighty or one hundred foot letter (*B* in the figure) to be seen or at least fixed upon by the eye, *A*, in its primary position by virtue of the double reflection of light by the mirrors *L* and *N* placed at an angle of about forty-five degrees with the line of sight. The double mirror device causes a lateral shifting of the letter or letters viewed; a single ray of light from the illuminated letter (*B*) to the macula (*M*) or fovea centralis is shown as *B—L—N—M*. The operator, *O*, with retinoscope at *R*, may then proceed to the skiametric refraction of the eye in a direction approximating the direct line of sight. By this device the possibility of incorrect findings will be reduced to a minimum if, by the use of mirrors as described, we can test close to the visual axis.

The writer uses the macular reflectoscope attached to the rod of his phoro-optometer by means of a special sleeve sliding along the rod ordinarily attached to the instrument and employed for carrying the reading and near muscle-test cards. This sleeve carries a screw permitting of its rigid clamping; through a socket at the side of this movable sleeve runs the rod carrying the mirrors. This gives practically every motion as to angle and height of mirrors desired and allows of its ready attachment to or removal from the optometer or can be swung by means of the rod out

retinoscope is stationed just back of one of the mirrors. This or any other scheme similar to the macular reflectoscope can also be used without trouble when a chart over the patient's head and a mirror at ten or so feet away are used in the testing room.

In his published writings, *Eberhardt* has called attention to some of the differences between ophthalmometric, subjective and retinoscopic findings upon the axis of cylinders correcting astigmatism and has pointed out the diagnostic value of retinoscopic findings made with the use of the macular reflectoscope in cyclophoric imbalance. Quite recently the writer has been the recipient of some very interesting letters from Mr. *Eberhardt* containing his expressions of opinion upon this topic and takes the liberty to quote from these communications the following sentences:

"This procedure, being monocular, the binocular functions become passive, the eye under observation assuming the position of greatest comfort. This has been found to be an important factor in oblique astigmatism, particularly where the obliquity of the axis is greater in one eye than in the other, thus imposing an abnormal demand upon the oblique muscles. Cyclophoric imbalances are often due to this condition. This enforced malfunctioning, if extended over a number of years, frequently manifests itself by apparently contradictory results obtained by subjective and objective procedures, a discrepancy being found in the position of the axis in subjective acuity tests, skiascopic refraction and corneal readings by the aid of the ophthalmometer."

And, again in another connection he writes: "In

the study of oblique astigmatism coupled with cyclophoria, I have found the macular skiascopic procedure most interesting; the very discrepancies between results obtained subjectively, by the skiascope and by the ophthalmometer furnished that differential data which enables an operator to make logical deductions by reasoning from cause to effect, always having in mind that the law of self-preservation dominates the human functions. This can be particularly appreciated in the case of irregular oblique astigmatism when, for example, the obliques have been forced over an extended period of years to rotate the two eyeballs so as to make fusion of the two retinal images possible, force of habit is such that, under the binocular acuity tests, the prime desire of vision will naturally bring with it, at least in part, the former torsional excursion. Under the condition of fog existing in skiascopy this is partially made passive, although the involuntary activity of the binocular functions still will dominate this acquired faulty functioning, whereas when corneal conditions are studied through the telescope of the ophthalmometer but little visual stimulus is present, as one eye simply looks into the tube and, one eye being occluded, binocular activity becomes passive. This is a fertile field for thought. I have hundreds of interesting cases on record where the solution was found * * * * to indicate a discrepancy between axes of cylinders accepted at infinity and those shown at the reading distance."

THE SCISSOR MOVEMENT IN RETINOSCOPY.

"Scissor movement" is a form of irregular astigmatism and is of sufficiently frequent occurrence in

retinoscopy to warrant further description and methods of handling such cases refractively than are given in our textbooks. In general terms, the shadow is split into two portions which, as the mirror is rotated, advance from opposite sides of the pupil and merge into one band giving the effect of closing a pair of scissors. On rotation of the mirror in the direction the reverse of that first employed the two oppositely moving reflexes again appear distinct and separate with a dark space intervening. Some uncertainty exists as to the cause of this phenomenon but it has probably been properly attributed, in general, to ectasia corneæ and slight tilting of the lens. In this latter condition the antero-posterior axis of the lens is not at right angles to the plane of the cornea. This tilted lens would cause one portion of the skiametric reflex to act myopically (light area moving against motion of plane mirror) and the other portion hyperopically. Scissor movement may therefore be due to coma on account of the obliquity of one or more surfaces of the dioptric media to the path of the incident light. This hypothesis is in part substantiated by the following facts:— (1) in an eye having a normal reflex by direct illumination, the scissor movement may be obtained by directing the beam of light obliquely, (2) a tilted spherical lens, especially if of fairly high power, in front of an eye may produce such an effect, (3) the effect can be artificially produced with schematic eyes by the use of obliquely directed light and (4) by a combination of lenses, in bifocal form or character, giving for example an effect of -3.00 D. in upper portion and $+3.00$ D. in lower portion placed before a

schematic eye set in emmetropic condition as described by *James Thorington, M. D.*, in the *Journal American Medical Association*, Dec., 1897.

Coma is aberration produced by the unequal refracting effects of different parts of the various meridians of the eye, or lens, on oblique pencils of light. It is, in brief, spherical aberration for oblique light; if this condition is produced optically we do not get a point image of a point object but rather a confusion disc which is non-symmetrical. In Figure 1 let L represent the crystalline lens in an oblique position. Assume that light has been thrown from the retinoscopic mirror into the eye; let A B represent the retinal area of illumination. The working distance lens is represented by W; for example, 1 D, for 1 meter. We are interested solely in the retinal reflexes or illumination returning to the observer assumed stationed at O. Let rays A N and B K be parallel rays of light emanating from the retinal area; the ray C M D E is the oblique principal axis. The ray B K reaches the surface of the lens sooner than the ray A N, and since B K departs more from minimum deviation than does A N (since the lens L may be considered as consisting of an infinite number of prisms) the emergent ray K D cuts the axial ray C E at D sooner or ahead of the emergent ray N E which cuts the axial ray at E. With the observer's eye at O we see from the diagram that it is possible (1) for the two reflexes, one myopic and one hyperopic, to be made to occupy one and the same position and (2) on motion of the mirror, since D is in front of the observer's nodal point and E is behind it, there will arise with and against movements or shadows.

*For Figure 1, see page 21.

Without doubt scissor motion may arise due to the obliquity of the light incident upon the eye under test. In the ordinary methods of procedure the patient is directed to look past the operator's ear and vaguely into space or at an illuminated test-type. A much better procedure and one which eliminates quite frequently these scissor movements, which are in these cases false in the sense that they are due to physical rather than anatomical reasons, has been devised by *John C. Eberhardt*, of Dayton, Ohio. Not only does this device do away with the liability to the above mentioned effects but it also insures the operator that the refraction at or near the macular area is being made retinoscopically which is a most important consideration. The device is diagrammatically shown in Figure 2 and has been described in some detail under the previous caption.

Laurance, in his *Visual Optics*, says: "In an eye suffering from a considerable degree of irregularity or aberration, the application of retinoscopy with success is difficult if not impossible. In many cases, however, a considerable improvement in the action of the shadow may be obtained by the observer shifting his position from one side to the other in order to utilize the areas of least error." *Thorington*, in his brochure on Retinoscopy, says: "These cases are more or less difficult to refract, but the presence of the two areas of light with the dark interspace will often assist in a correct selection of glasses, for while they are generally of the compound hyperopic types, calling for a plus sphere and plus cylinder, yet practice and the patient's statement often call for a plus sphere and

minus cylinder * * * The writer's method of procedure when he recognizes the scissor movement is to tilt the mirror until the two areas are brought into one band of light and then to reflect the light through the meridian of this band. Having obtained the lens which neutralizes the movement in this meridian, the writer does not attempt to find the neutralizing lens for the opposite meridian but goes from the dark room to the trial case and places before the patient's eye that sphere which corrects the refraction in the one meridian."

These statements are quoted at some length from these treatises because they contain about the only information available. For my own part, I have made a study of some fifty cases of scissor movement and shall present some few here, with diagrams, to illustrate the general methods of procedure and the determination of the proper cylinders to be prescribed. Above all it is important and essential that the retinoscopic refraction of such cases be made as nearly as possible in the direct line of sight; this is possible by the use of a device such as the so-called macular reflectoscope previously referred to or by dynamic skiametry. In this latter method fixation is elicited for a letter or set of letters or points on a card attached close to the mirror of the retinoscope; a neutralization skiascopically of one meridian by a sphere then leaves the opposite meridian to be corrected with cylinders, hence making it possible to determine the cylindrical element correctly irrespective of the operator's opinion as to the refractive accuracy of the spherical element found. When an eye is under com-

plete cycloplegia these methods are still applicable although, of course, the dynamic method is not dynamic but simply serves as a method of directing the patient's gaze; under cycloplegics the refraction in the line of sight can be accomplished very readily except for the disadvantage of peripheral rays which add to the already complicated problem. The general mode of procedure is, then, to neutralize the motion in the meridian opposite to that in which the scissor movement arises, keeping the two bands together as is advocated by *Thorington*. Having neutralized this meridian with spheres the writer then proceeds to the correction of the meridian in which the scissor movement has evidenced itself in the following manner; the two bands are brought together and the position of the line of union into a single band in the pupil is noted, i. e. whether, as it forms, it is the nasal, temporal, supra or infra side. The mirror is then rotated in the opposite direction slowly and the positions of the two bands just at their line of separation are noted and *that portion of the double reflex which contains within itself the center of the pupil*, or which in any way gives evidence that it discloses the chiefly usable portion of the eye, is corrected with cylinders. In case of doubt as to which shadow to heed, since the line of demarcation may arise near the pupillary center, I have found it in general proper procedure to neutralize the nasal or the infra portions respectively. The greater percentage of cases show the scissor bands lying at or near the 180° line of the trial frame, but some few cases, particularly those giving a history of traumatism in the temporal region, exhibit these bands at or near the 90° point.

Case 3. (See Figure 3 A.) O. D. -0.62 D. S. $\odot$
 -0.50 cyl. ax. 90 ; $V=20/20$ O. S. -0.62 D. S. $\odot$
 $+0.37$ cyl. ax. 90 ; $V=20/20$. Left eye exhibited scissor motion after the addition of -0.50 D. S. ($+1$ D.

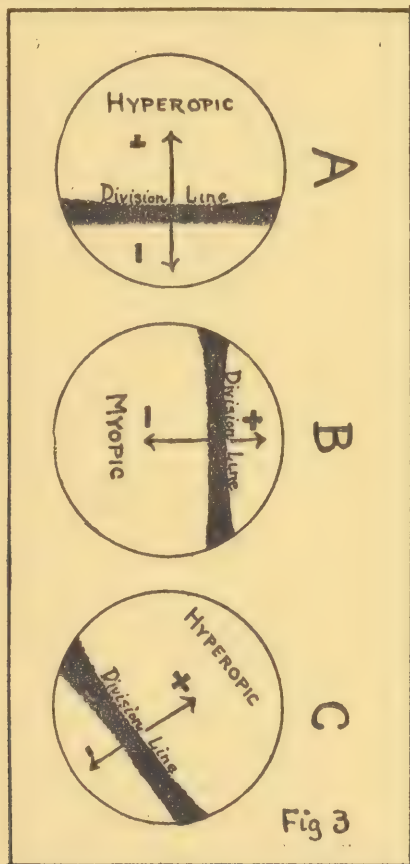


Figure 3. Illustrative of the Position of the Bands in Scissor Movement.

S. used throughout these cases as the working distance lens.) It was found that -0.62 D. S. neutralized all motion in the vertical direction; in the horizontal direction the two bands united into one in the temporal quadrant; upon separation the hyperopic (with) reflex occupied three-fourths of the pupil; $+0.37$ cyl. ax. 90, in addition to the lenses used previously to neutralize the first meridian, corrected the with motion and -0.25 cyl. ax. 90 corrected the against movement occupying the temporal quadrant. With -0.62 D. S. $\ominus +0.37$ cyl. ax. 90 $V=10/10$ readily; with -0.62 D. S. $\ominus -0.25$ cyl. ax. 90 $V=7/10$ to $8/10$ with two errors; had been wearing for some years -0.50 D. S. $\ominus -0.37$ cyl. ax. 90 and told the writer that the vision in this eye was not very good and never had been. Under oblique illumination, by the way, an operator would have been justified in concluding that the minus cylinder was demanded. The ophthalmometer showed no corneal irregularity; the clock-dial test elicited somewhat uncertain and changeable answers.

Case 4. (See Figure 3B.) Right eye; division line above the center of the pupil; attention given to the lower portion only. A $+1.50$ D. S., working at one meter, gave neutral shadow in the horizontal meridian; in addition thereto -1.50 cyl. ax. 180 neutralized motion in lower portion of pupil. With $+0.50$ D. S. $\ominus -1.50$ cyl. ax. 180, $V=20/20$ to $20/16$. A $+1.00$ cyl. ax. 180 apparently neutralized the upper and hyperopic portion, but subjectively $+0.50$ D. S. $\ominus +1.00$ cyl. ax. 180 gave $V=10/20$ to $12/20$ with two errors.

Case 5. (See Figure 3C.) Right eye; band forms and division occurs along the 30° line; the hyperopic

or with portion constituted about three-fourths of the total reflex. A -1.50 D. S. neutralized motion along the 30° line or the line of the single band when the two were brought together. The upper, temporal portion of the scissors movement was neutralized with $+2.00$ cyl. ax. 30 , the lower or against movement with a -1.50 cyl. ax. 30 . The subjective tests showed that with -1.50 D. S. $\ominus +2.00$ cyl. ax. 30 , $V=9/10$, while the minus-minus combination was absolutely impossible. The ophthalmometer showed a slightly irregular cornea; the amount of corneal astigmatic error did not exceed 0.75 D. as nearly as could be determined. As a further test this case was clinically checked by use of a narrow stenopaic slit; the best vision slit position was at 120° , the poorest vision slit position was at 30° . With the slit in the 120° position $+0.50$ sphere gave $V=10/10$ and with the slit at the 30° position -1.50 sphere gave $V=9/10$. This gives as the cylindrical corrections $+0.50$ cyl. ax. $30 \ominus -1.50$ cyl. ax. 120 and as a sphero-cylinder -1.50 D. S. $\ominus +2.00$ cyl. ax. 30 or $+0.50$ D. S. $\ominus -2.00$ cyl. ax. 120° . In this instance, as in many others, it was discovered that one equivalent form was much more satisfactory to the patient than the other; why, the writer is unable to state except that the irregular astigmatic condition apparently demands that it be corrected per se; it is also to be noted that, in nearly all cases, the lens values needed to correct the two portions of the scissor motion are not equal. The satisfactory results to be obtained by the use of a narrow stenopaic slit in such cases, either in the initial or corroborative testings, is worthy of comment.

The chief points to which attention has been called are briefly as follows: (1) The desirability of and necessity for obtaining the retinoscopic findings as nearly as possible in the direct line of sight. Many scissor movements will not then evidence themselves although present under oblique examination (2) When a scissor movement arises, determine position of the single band just as the two bands close together and again the position of the division line just as the two bands re-appear; correct retinoscopically by the addition of cylinders to the lens quantity already present the astigmatic band which contains within itself the center of the pupil or which gives evidence that it discloses the chiefly usable portion of the eye. (3) In case of doubt correct retinoscopically the nasal or the lower (infra) portion of the double reflex respectively and subject to rigid subjective testings. (4) A slight overcorrection of the meridian first corrected may either do away with the scissor movement or aid in the determination of which portion thereof is to be corrected. (5) The use of a narrow stenopaic slit in such cases is a valuable corroborative test.

We shall pass over and deal in subsequent chapters with the topics of Dynamic Skiametric Tests, Monocular and Binocular Objective Tests upon the Amplitude of Accommodation, Accommodation Associated with Convergence as Tested at the Reading Point, Tests upon Cyclophoria and Hyperphoric Conditions at the Reading Point, Fusional Reserve Convergence and Monocular Tests upon the Amplitude of Accommodation using Concave Lenses at the Thirteen Inch Point. We shall omit all discussion upon Subjective

Acuity Tests and allied topics, except to point out some of the niceties of subjective testing as made possible by Comparison Tests as to the Equality of Visual Acuity and the Range and Amplitude of Accommodation.

COMPARISON TESTS AT DISTANCE USING SMALL, EQUAL
PRISMS BASE UP AND DOWN BEFORE EACH
EYE RESPECTIVELY.

Immediate contrast is the keynote of success in the equalizing of visual acuity—whether the tests be conducted at distance or reading points. The alternate and rapid occlusion of first one eye and then the other is a simple means of obtaining this contrast, but it can be improved upon greatly both as to ease of comparison and lack of annoyance to the patient, who generally makes the request, under the card occlusion test, to “please repeat the test” just described. The writer generally makes this alternate occlusion comparison test before trying out for muscular imbalances at distance. Immediately after, or sometimes between the tests for lateral and vertical equipoise, the writer turns back from the “muscle light” to the 20 or 24-foot line on the Twentieth Century Test Cabinet—thus far this is probably the best test chart of its kind on the market—and places a 1° to 2° prism base down before the right eye and a corresponding prism base up before the left eye. The purpose of the division of the prism between the eyes is to insure equality of optical conditions in so far as the testing appurtenances are concerned. By this statement we do not refer to distortion or similar effects, because these are small and negligible when such low prism diopters are used, and if any such effects should occur they would not be

alike in both eyes, since one of the prisms is base up and the other is base down. We have reference to the fact that a total of 2° to 4° is generally insuperable to the vertically acting recti and hence insuperable diplopia will result; if the prism were wholly before one eye the "un-prismed" eye would be fixing macularly, while if the prism is divided between the two eyes the retinal images are received at an equal angular distance from the fovea centralis in each eye and are therefore received upon normally equally form-sensitive portions of the retinas. Hence, with these low powered prisms, base up and base down respectively before each eye, *the patient sees simultaneously two lines of test type and can rapidly and with ease direct his or her attention to first one space-image or line of type seen and then to the other and intelligently report upon their equality.* A point, which is psychological in nature, which adds to the value of this test, is that the subject's interest is aroused in the actual creation of the diplopia and his co-operation is engendered. Such changes are then made as ensure equal acuity; these findings may be subsequently *binocularly* increased or decreased in spherical values in the light of various dynamic tests upon the accommodation and convergence.

The practitioner should never be at a loss as to which image corresponds to or belongs to which eye; if the prisms are O. D. base down, and O. S. base up, the upper image or line of type will be seen in space by the right eye and the lower by the left eye. The prisms placed before the eyes cause deviations of rays of light toward their bases; the retinal images are projected

back into space through the ocular nodal points of each eye according to the fundamental law of projections. The images in space, i. e., the objects seen, will therefore be seen displaced in all cases such as this toward the apex of the prism or away from its base.

In passing let it be stated that the cover test, involving an alternate, rapid occlusion of each eye in turn, furnishes a delicate test for small amounts of *vertical imbalance*, i. e., hyperphoria or hypophoria. The patient is requested to note whether, as the card is shifted quickly from one eye to the other, the line of type appears to remain fixed or constant in a horizontal direction or whether there is a slight alternate upward and downward motion of the images as seen by the eyes in turn. To illustrate: Assume that under this test the image as seen by the right eye appears higher than that seen by the left, such that on rapid oscillation of the card the image of the right eye seems to ascend and that of the left eye to descend. Or assume, for purposes of further illustration, that the two lines of type shown in Figure 5 (supposedly representing a line of type on the distance chart) diagram the relative positions of the images as seen by the two eyes. Let the upper be seen by the right eye and the lower by the left so that under rapid alternate occlusion there is what may be designated as a "step-up, step-down" performance. We should conclude from this evidence that the right eye turns downward, relatively speaking, or the left eye relatively upward, requiring a prism base up O. D. or prism base down O. S. to produce equality of level of these images and hence correct the vertical imbalance.

36 THE ROUTINE OF AN EYE EXAMINATION.

THE COMPARISON TEST AT THE READING POINT AND SOME IMPORTANT CONSIDERATIONS IN CONNECTION THEREWITH.

Comparison tests at the reading point may be made by either of the two methods described above; in fact, both of them should be used in the course of an examination. The ordinary near-test card is handed the patient and reading is engaged in while the cover is fairly rapidly passed from one eye to the other. Differences in apparent size and color are often noticeable; this test should be safeguarded against false color impressions, such as the appearance of a reddish or bluish background upon which the printed words occur, by the exclusion of auxiliary sidelights; that is, the illumination should be uniform and by the indirect lighting system where possible or subdued in character and the card so held as to prevent direct reflection of light from the surface of the reading card into the subject's eyes. The test type, usually No. 2 Jaeger (Snellen V=5 D.), should be then approached toward the eye and the monocular near point determined for each eye and their equality or inequality determined upon. This affords a test upon the range and the amplitude of accommodation as subjectively determined from near point investigations. Many cases will arise in which the addition of a small sphere to one or the other eye will establish conditions of equality and which, upon subsequent test at distance, will prove as satisfactory from that standpoint also.

The writer is, however, rather partial to and prone to depend upon a comparison test at the reading point by the method of prisms. The procedure is practically

the same as outlined in connection with the use of this method as employed by the author in distance observations. Quite commonly a 4° base down before the

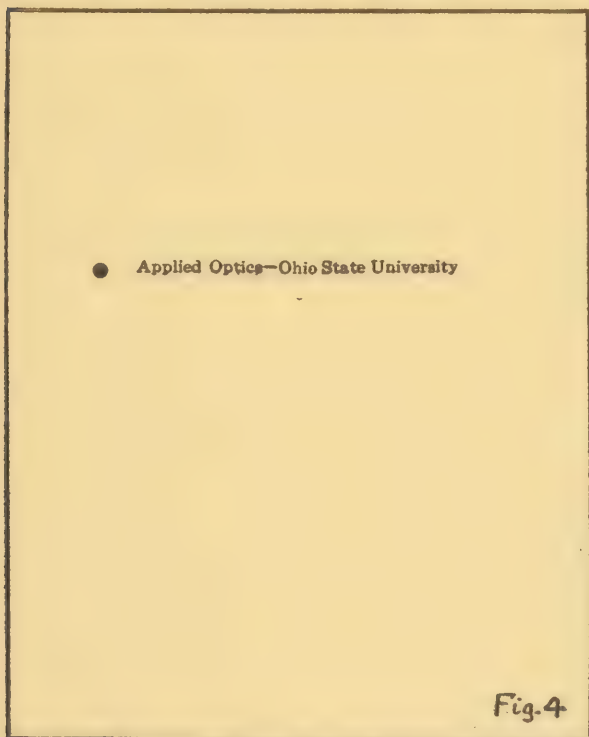


Figure 4. Test Line Used in The Comparison of Acuity and Equality of Range and Amplitude of Accommodation.

right eye and a 4° base up before the left eye are used and a test card carrying a single dot with a line of type, such as shown in Figure 4, has been used by the writer. This card is held at about thirteen inches for

the initial comparison test. The card is then slowly approached by the patient toward his eyes and the equality or inequality of range and amplitude of accommodation established. The positions of the images as seen by each of the eyes thus *fusionally* dissociated—i. e., in which binocular vision is not in vogue but in which monocular accommodation can be brought into play—follow the rule that the space-image appears in each case displaced toward the apex of the prism or away from its base.

Under what we believe to be normal conditions of convergence as associated with accommodation at the thirteen inch reading point, with fusional convergence passive, there will be found a *physiologic exophoria* of 5° to 6° (vide, the writings of *Maddox, Stevens, Howe and Worth*). Bearing in mind the law of projection and the physiology of exophoria—in which, for example, if the eyes are relatively exophoric, the retinal image in the right eye will be received on the temporal side of the macula and hence be projected *through the nodal point* into space and produce the spatial image to the nasal side, and so forth—there will be a condition of crossed (heteronymous) images. If, therefore, normal relations between accommodation and the associated convergence exist, some 5° to 6° of prism, base in, will be needed to bring the two dots into a vertical line or row. These innervational conditions, as well as those pertaining to equality of visual acuity and which are here assumed to be a true test for equality of accommodative action when equality of acuity exists at twenty feet, may be simultaneously investigated. These optical effects under fu-

sional dissociation by means of equal prisms base up and base down before each eye respectively are diagrammed in Figure 5.

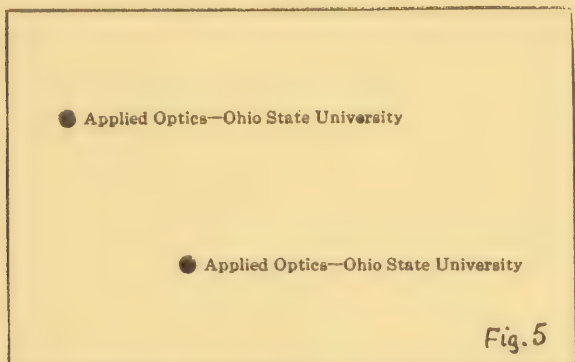


Figure 5. Images as Seen Under Fusional Dissociation by Means of Vertically Placed Prisms.

To revert to the question of equality of accommodative amplitude and range, the writer has found that the use of a 4° prism respectively before each eye produces at thirteen inches a separation of the two spatial images of such large extent as to make easy comparison somewhat difficult and less certain than is desirable. The procedure in this test has, therefore, been modified somewhat as follows. The card, Figure 4, of extra quality as to weight and whiteness of surface, about 4 by 5 inches in size and printed in No. 2 or No. 3 Jaeger type, is inserted in the carrier attached to the rod of the phorometer and the two rotary prisms are then thrown into position and each rotated equally but in opposite directions until two lines of type, situated about one-half inch apart, are seen. Equality of

acuity, if not present, is next established and the card is then approached to the approximate punctum proximum and the prism powers increased (since the two images, for obvious optical reasons, approach each other and may merge into one another as the card is moved nearer the eyes) until they are about a half inch apart vertically. Should the image as seen by the right eye, for instance, be readable at a closer point than that seen by its mate, the operator knows that the range and equality of accommodative action are unequal and proceeds to establish such equalization when possible.

If an additional quarter or half diopter is needed before an eye to re-establish visual equality, this fact is noted in the record of the case and subsequent tests are made at distance to determine whether or not full accommodative relaxation has previously been obtained in the distance tests, or whether or not this additional correction is not practically as acceptable for distant vision as the finding initially determined upon. The writer has come to look upon such inequalities under such conditions as portrayed at the reading point or at the punctum proximum as in general indicative of failure to obtain as complete an accommodative relaxation at distance as possible. When this is not the case, and when inequalities of accommodation do present themselves, we have present those extremely interesting ocular conditions which demand skill in their handling and which often demand separate distance and near corrections.

The value of this method in presbyopia must likewise be apparent to the reader. There is no more

reason for believing and assuming, as is generally done, that the accommodative reserve and the accommodative assistance demanded in presbyopia should be the same in both eyes than there is in pre-presbyopic conditions. Equality of range and amplitude of accommodation in presbyopic cases and the near and far reading points can be determined upon with rapidity, ease and accuracy by means of this comparison test involving fusional dissociation while accommodation and its associated convergence are left active.

THREE ESSENTIAL DYNAMIC TESTS FOR THE EXTRINSIC EYE MUSCLES.

We have quoted almost verbatim the title of one of the sections in *Dr. G. C. Savage's* essay on "Ocular Muscles" appearing in the tenth volume of *The American Encyclopedia of Ophthalmology*. We quote liberally from his statements upon this topic. "There are three tests which should be made of every pair of eyes as part of the work of refraction. To neglect the making of these tests will mark many failures against the oculist. Tonicity, duction and version are the names of these tests. The two first mentioned are indispensable; the last one named is of so much value as to command attention. In a very crude way the tonicity and fusion tests may be made with the loose prisms in the refraction case, but better far is the monocular phorometer. The binocular phorometer should not be used for either of these tests, for the fundamental reason that the image of the test object in one eye should be undisturbed. The principle on which all the tests possible to a phorometer rest, is that the image in one eye, throughout every test, shall be undisturbed; that

the head shall be erect; and that both eyes and the object—better a white dot on a black background—shall be on the extended horizontal plane of the head. The false object must have its image thrown outside the area of binocular fusion in the eye under test * * *.”

In our opinion, however, many of these tests are not as valuable to the refractionist as are the tonicity tests conducted at twenty feet when taken in conjunction with the findings upon the accommodative amplitude, the accommodation as associated with the convergence and the fusional convergence at the reading point or thirteen inches. These distance tonicity, duction and version tests do, however, form a valid basis for the determination of whether or not innervations or strengths or attachments of muscles are at fault since, in general, practically normal duction and verting powers indicate—in cases of tonicity excesses or lack of proper coordination between accommodation and convergence—innervational excesses or deficiencies and not inherent muscle abnormalities. For instance, if tonicity tests indicate several degrees of exophoria, adduction powers considerably below the normally accepted three to one ratio as compared with abduction, and adversion low or abversion excessively high we may with reason conclude that there is a muscular rather than innervational deficiency of the interni. It is, however, to be remarked that duction tests at 20 feet, with the patient wearing his full distance correction, presume that positive or negative convergence and so forth are exercised with the function of accommodation passive. Such duction tests conducted at distance must, therefore, be a measure of the ability

of the *fusional centers*, wholly independently of accommodation, to overcome the tonicity defect (or be aided by it, dependent upon whether this equilibrium condition is one of exophoria or esophoria) and to maintain binocular single vision. In the customary circumstances under which convergence is called into play accommodation is also demanded and, as we hope to show later on, there is normally associated with the accommodation about two-thirds of the full positive convergence needed for binocular single vision at any given point, the remaining demand being met by the fusional or reserve convergence. If, again, it is assumed, as so many writers do, that convergence and accommodation are so closely related that the accommodation and accommodative-convergence points are one and the same, then the duction tests at infinity are presumed, it seems to the writer, to measure simply the power to overcome tonicity deficiencies and to supply any needed positive or negative convergence, if such is needed, at near points. We do not, therefore, as a general rule, take the duction and version tests unless the tonicity tests show large errors, but are prone to depend in general upon the disclosures at the reading point. And again, one of the inflexible rules which must underlie the investigation of any given ocular function is "that such investigations must be conducted under conditions of activity and quiescence which conform to the philosophy of the particular phase of its activity under consideration." Convergence demands are normally made and met at points inside of infinity (practically, 20 feet). *Maddox*, to my mind, comes nearer the true method when he writes:—"To measure

more accurately, we should first discover the near point of accommodation, and while looking at an object at that distance from the double rotating prism frame, rotate the edges of the prism inwards until diplopia commences. By adding the maximum convergence thus found to the already ascertained prism-divergence for distance, we get the 'absolute range (amplitude) of convergence', of which according to *Dr. Landolt, not more than one-third or one-fourth can be continuously in exercise for comfortable vision.*"

The *monocular tonicity and duction tests* are most valuable, however, in locating the single weak muscle of a pair of muscles and often show that the ductions of the extrinsic muscles of one eye are normal while the abduction, adduction, superduction or subduction of its mate is faulty. Hyperphoria and hypophoria are relative conditions corrigible by prisms base up before one eye or base down before the other or *vice versa*, or the prismatic assistance may be divided between the eyes. Vertical imbalances are generally of much greater importance than are the lateral imbalances and greater care and skill are demanded in their optical treatment than in low degrees of exophoria or esophoria; it is, therefore, very essential that the weak ductioned muscle or muscles be determined in order to logically proceed to its alleviation or optical assistance in a manner such as will tend to restore its normal functions where possible. Since the duction powers of the vertical muscles are low, great care needs to be exercised in their treatment; if such is true, the writer believes that some auxiliary device should be provided

in our modern phorometers in order that our vertical ductions may be determined with more certainty than is possible with our present rotary prisms in which the prismatic power changes are too rapid for the small amount of mechanical motion involved.

DUCTION TESTS OF THE RECTI MUSCLES.

Duction is fusional and not volitional and is under the control of the fusion centers operating in the interests of binocular single vision. If, in an eye, the image is displaced into any part of its fusional domain, the fusional faculty will move the macula to it when possible. As *Savage* says:—"When an image is displaced by a prism to any point within the field of fusion of an eye, while the image in the other eye remains upon the macula, an effort at fusion will be made, and if the muscle that must respond is sufficiently strong, fusion will at once take place, caused by such a rotation as will bring the macula under the displaced image. When the image is thrown, by a stronger prism, entirely outside of the field of fusion, the guiding sensation, which seems to reside in this area only, will not call on any muscle to move the eye for the purpose of fusion. The nasal limit of this retinal area, as measured by a prism in front of the eye, is 8° ; the temporal limit, 25° ; the upper limit, 3° , and the lower limit, 3° . The line drawn through these four points marks the entire boundary of the field. These may be considered as the normal size of the fusion area." The field of binocular fusion is the peculiar kite-shaped area in each retina shown in Figure 6 (due to *Savage*).

Hence, in duction tests, when a prism is located be-

fore one eye, the fellow eye fixing a definite luminous test object at five or six meters distance, and the base

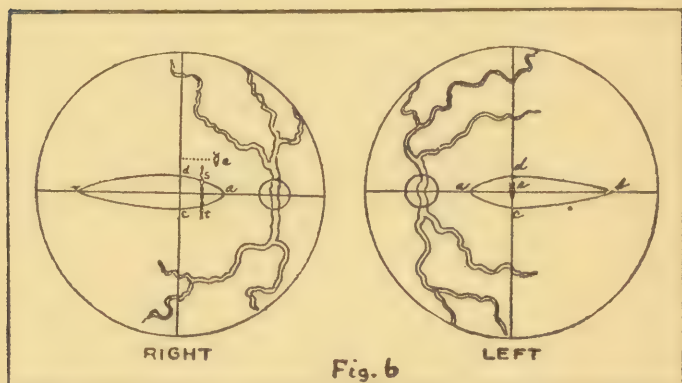


Figure 6. Fusion Fields of the Recti Muscles. (From Savage.)

of the prism is accurately in, out, up or down, *only that rectus muscle lying beneath the apex of the prism is stimulated into action.* All other muscles of both eyes remain passive in so far as the prism effects are concerned. The *independent contractile power* or range of dissociated action of each rectus may be accurately measured and values compared such that, in many cases, the origin of the imbalance may be determined.

An accurate and well centered correction for the observer's ametropia should be in place during these tests.

To test the adduction, or contractile power of the internus, of the right eye, a double rotary prism should be placed before this (right) eye and base *out* turned

in the mobile prism until the object is seen double. Several tests should be taken and in general averaged. The abduction of this same eye may be obtained by causing a variable prism value, base *in*, to be placed before the eye until diplopia is obtained. Similar procedures are instituted for obtaining the vertical rectifications; for superduction, prism base down should be employed and for subduction, base up used until doubleness of object occurs vertically.

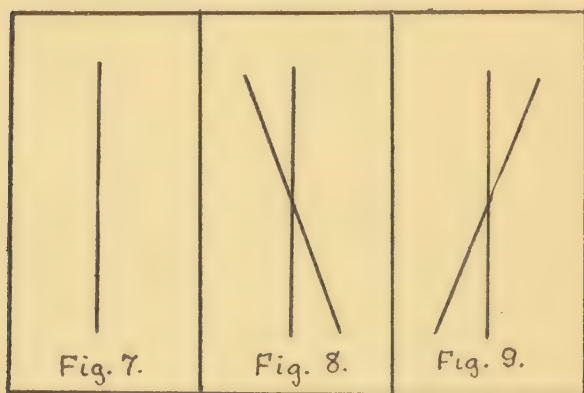
To test the ductions of the left eye one proceeds in a like manner with the rotary prism before the eye to be tested.

A comparison of the results obtained for the two eyes indicates which muscles are lacking in tone, and muscle exercise, prismatic corrections or operative procedure may then be advised or engaged in with a knowledge of the requirements in nearly all instances.

DUCTION TESTS OF THE OBLIQUE MUSCLES.

Duction tests upon the oblique muscles may be made by means of two Maddox graduated rods placed so as to give a vertical band or ribbon of light. One ribbon only should be seen; if two are present the lateral imbalance should be properly rectified by prisms base in or out (in high exophoria or esophoria) and the tests then instituted. *DeZeng*, in his compendium on "The Modern Phorometer," says: "To make this test, place a Maddox graduated multiple white rod in operative position before each eye with the axis of each horizontal and employ a luminous test object about 10 mm. in diameter, located five or six meters distant in the dark room and in direct alignment with the phorometer. Should the observer be either ametropic or

heterophoric, or both, a suitable correction should be in place, as no action by the recti is desirable during these tests. The observer should see but one band of light, Figure 7, and to measure the duction range of the superior oblique of the right eye, the rod on the corresponding side of the instrument should be rotated slowly and steadily downward at its nasal end until the band of light begins to break, or assume the appearance somewhat of the letter X, Figure 8, whereupon the position of the indicator with respect to the inner scale will denote the degree of right minus cycloduction. Upon returning the rod to its former posi-



Figures 7-9. Illustrating the Images Seen Under Duction Tests of the Oblique Muscles.

tion for a moment and indicator at zero, it may be rotated downward at the temporal end until the vertical band of light breaks in the opposite direction, Figure 9, whereupon the position of the indicator with respect to the outer scale will denote the duction range

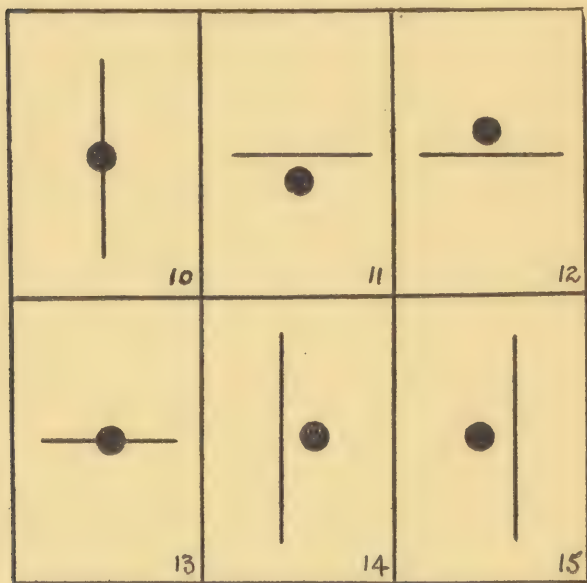
of the right inferior oblique, or the degree of right plus cycloduction. The plus and minus cycloduction of the left eye may be taken in like manner and the results obtained in each instance recorded for comparison. The duction range of the oblique muscles when taken in this way will average from 5 to 20 degree of arc. The Maddox rods employed in this test should both be *white*, otherwise the full fusion effort of the oblique muscles will not be obtained."

TONICITY TESTS UPON THE RECTI MUSCLES.

The Binocular Test. The tests upon the vertical and lateral imbalances of a pair of eyes as ordinarily made by means of the Maddox multiple rod, giving a band of light, before one eye and a distance small luminous source or test object at five or six meters being viewed by its mate, in reality constitutes a binocular test. This is so for the reason that the false image—the band of light—has its image thrown within the area of binocular fusion of the eye under test, while the true object will have its image on the macula of the eye not under test. Hence this test *may* indicate the character and approximately correct amount of any existing vertical or horizontal imbalance but, due to its binocular character, will neither locate the faulty image nor the consequently deviating eye.

Figures 10 to 15 show the relative positions of the band of light and the luminous test object when the Maddox rod is placed before the *left* eye. Figure 10 indicates binocular lateral orthophoria, Figure 11 right hyperphoria, Figure 12 left hyperphoria, Figure 13 binocular vertical orthophoria, Figure 14 esophoria and Figure 15 exophoria.

The following simple rule will aid in the mnemonics of tonicity tests:—According to the law of projection the image is referred back into space and is seen in the position or the direction from which it should, under normal conditions, have proceeded from the spatial object. If the retinal image falls to the nasal side of the macula it will be projected into space



Figures 10-15. Illustrating the Images as Seen in the Binocular Tests upon The Tonicity of the Recti Muscles.

through the nodal point of the eye and be seen on the temporal side, and so forth; or if the ribbon of light falls retinally above the macula it will be seen in space

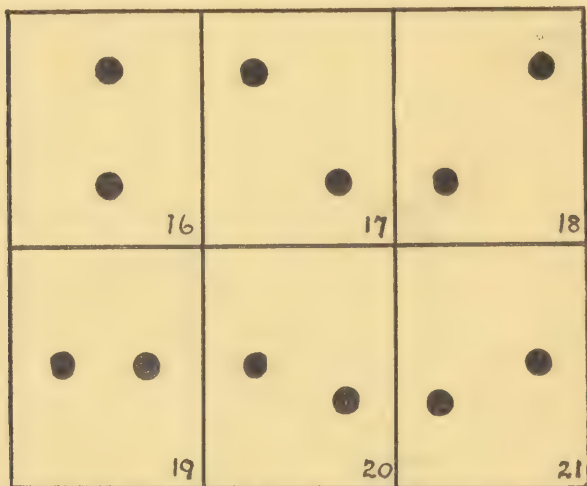
infrally (below). The displacement or equilibrium position of the eye is such that its rotation is in the same direction as the retinal image displacement or opposite to that of the object-image. Hence, in lateral imbalances, if the band of light is seen on the same side as the eye carrying the Maddox rod, there is a condition of esophoria; if the images are crossed, exophoria; if, in vertical imbalances, the streak is seen above the light, there is left hypophoria and if seen below the light, left hyperphoria relatively.

The writer likewise believes that such tests as the *Stevenson* Muscle Test or the *Maddox* Tangent Scale, carrying a long vertical line to serve as a pointer or indicator, (or a line of type with an arrow directly below it) and doubleness of image produced by means of vertically displacing prisms, are not trustworthy in their measurements of exophoria and esophoria, since the images of these lines, falling within the fusion areas, stimulate fusion. A similar statement may be made with reference to these same tests when used in any form in investigating hyperphoria and cataphoria. The writer hopes soon to publish the results of a detailed investigation upon this topic.

Monocular Tests. Hardly a week goes by that someone does not write or ask the author about monocular tonicity tests. In reply we have generally referred the inquirer to *Savage's* "Ophthalmic Myology"—a book which should be read by every eye practitioner, as well as *Stevens'* "The Motor Apparatus of the Eye." The principle involved is that which we have previously stated, namely: *The false image must fall outside of the fusion area.* This is easily

accomplished by putting an 8° prism, base up, before one eye in testing lateral imbalances and a 10° to 12° prism, base in, before one eye in testing for vertical imbalances. These results are shown in Figures 16 to 21. Figure 16 shows, with the vertical displacing prism before the right eye, lateral orthophoria, Figure 17 right esophoria, Figure 18 right exophoria. Figure 19, with 12° base in before the right eye, shows no vertical heterophoria, Figure 20 shows right hyperphoria and Figure 21 right cataphoria.

To test, then, the lateral imbalance of the right eye, we place a mobile or rotary double prism before this (right) eye and rotate the prisms until there is eight prism diopters base up. This will displace the test object seen by this eye downward beyond the fusion



Figures 16-21. Illustrating the Images as Seen in the Monocular Tonicity Investigations.

range and thus produce insuperable diplopia. The lower, or false image, is then seen by the right eye, while the upper, or true, object is seen by the other. The heterophoric or orthophoric condition of the right eye is thus under test and the requisite amount of prism, base in or out, in cases of exophoria and esophoria, can be obtained by use of a second prism before the left eye. The lateral balance of the left eye can be tested in a similar manner, i. e. by putting about eight prism diopters base up before it. In testing the vertical tonicity of the right eye, some twelve prism diopters, base in, are placed before this (right) eye and insuperable horizontal diplopia produced. The right eye receives, therefore, the displaced image, and its location above or below the horizontal plane of the image as seen by the left eye indicates the nature of the heterophoria which can be compensated by the use of a second rotary prism before the left eye with prism, base up or down, as the case may be.

A discussion of these tonicity tests is included in this treatise for the reason that due precautions should be taken in order to ensure that *fusion*, which is a *dynamic* and *not static* function, shall be eliminated.

VERSION TESTS.

The rotations in the four cardinal directions are those to be studied. The best instrument for these tests is the tropometer of *Stevens* (*vide* Stevens: "The Motor Apparatus of the Eye"). A very satisfactory test may, however, be made with the perimeter and the small electric lamp of the ophthalmoscope. The patient should be placed in front of the perimeter

while the eye to be tested must be at the center of the perimetric curve. The patient's head should be then kept immobile. The extent of the abversion is determined by having the subject fix the small electric lamp as it is moved behind the perimetric arc or arm toward the temporal side of the eye under test. When maximum version has been produced the operator places the lamp so that the lamp image occupies the center of the rotated cornea and reads the degree mark on the perimetric scale opposite the luminous source used. The rotation in the opposite direction, or the adversion, can be obtained in a like manner. With the perimeter arms vertical, the extent of the upward and downward versions can be determined. Both eyes should be thus tested. The extent of the versions under normal conditions as given by different authors varies somewhat. *Landolt* gives: Out 46° , in 44° , down 50° , up 33° . *Stevens'* standard, which is probably nearer correct, gives: Out 48° to 53° , in 48° to 53° , down 50° , up 35° . A muscle that has the normal fusion or duction power should also have normal verting power and in general, when one is abnormal, the other is likely to be abnormal also.

We close this chapter and discussion on the distance dynamic tests upon duction and version by a citation of two illustrative cases.

Case 6. Mr. A. W. Aet. 25 years. A teacher by profession. Has been examined previously and been told that there was no accommodative, refractive or astigmatic errors. Tests previously made under a mydriatic disclosed little spherical correction. Has, however, uncomfortable coordination of his eyes.

Static retinoscopy disclosed no refractive errors and subjective monocular and binocular tests failed to elicit comfortable vision under low powered spheres. *Dynamic* skiametry disclosed O. U. +1.00 D. S. In the prescriptions finally given this young man, one involved a reading correction of O. U. +0.75 D. S. combined with the distance prismatic correction to be later disclosed. *Binocular tonicity* tests showed 5° of exophoria and 3° of left hyperphoria. The duction tests demonstrated the following:—

DUCTIONS.

O. D.	O. S.
Abduction4 to 6°	Abduction8°
Adduction8 to 10°	Adduction12°
Superduction1°	Superduction4°
Subduction4°	Subduction1°

The version tests showed:

VERSIONS.

O. D.	O. S.
Abversion48°	Abversion50°
Adversion42°	Adversion46°
Supversion27°	Supversion35°
Subversion55°	Subversion48°

Tests at the reading point, after the manner to be described in the next chapter, showed 11° of exophoria and 3° of left hyperphoria. The fusional reserve convergence at the reading point was about 10°. The data indicates that the interni are both weak ductionally and versionally and that the reserve convergence at the reading point is low; these tests also show that the abduction and adduction are about normal and that the right superior and left inferior are subnormal

in their powers. For distant use we therefore prescribed:

O. D. 1° base up $\ominus 1.5^{\circ}$ base in.

O. S. 1° base down $\ominus 1^{\circ}$ base in.

We likewise instituted prismatic exercises and the simple 'toward the nose movement of the finger' in order to restore normal lateral equipoise but without success. The glasses, according to the prescription written above, the patient has worn with perfect comfort and ocular coordination for over three years. In the record of the case we find the note that when the above corrections (slightly increased, however) were worn there was no cyclophoria present but that without such corrections several degrees of cyclophoria were apparently exhibited.

Case 7. Mr. E. Aged 35 years. History of melancholia, uncertainty in gaze and walk, very nervous. Severe headaches and so forth. Various tests showed that O. D. $+1.00$ D. S. $\ominus +0.50$ cyl. ax 75 and O. S. $+1.25$ D. S. $\ominus +0.37$ cyl. ax. 105 gave normal and equal acuity. The *binocular tonicity* tests showed 9° exophoria and 4° left hyperphoria. At thirteen inches various tests showed 12° exophoria and 4° base up O. D. The ductions evidenced: O. D. abduction 9° , adduction 15° supraduction 1° , infraduction 2° ; O. S. abduction 11° , adduction 14° , supraduction 2° and infraduction 1° . Version tests did not prove out satisfactorily or consistently; adversions apparently weak in both eyes however. The fusional reserve convergence at thirteen inches was approximately 5° , but this was erratic in character. Tests upon the accommodation disclosed a practical paresis

thereof. We were entitled, then, from the above data and his history, as well as from other data not here recorded, to diagnose an involvement of the third nerve and to recommend him to a specialist. This he did with the report that the statement had been made that his hay-fever of long years standing had apparently involved the sinuses. To give him as much ocular comfort as possible we gave him, in addition to the sphero-cylinder corrections both for distance and near, the following:— O. D. 2° base in $\subset$ 1° base up and O. S., 2° base in $\subset$ 1° base down.

REFERENCES.

- Savage.* Ophthalmic Myology. Pages 146-179
Neuro-Myology. Pages 1-54.
Ocular Muscles. Am. Ency. Ophthalmology, Vol. X, pages 7975-7992.
- Laurance.* Visual Optics. Pages 152-194.
- Maddox.* The Ocular Muscles. Pages 213-251.
Ophthalmological Prisms. Pages 66-100.
- DeZeng.* The Modern Phorometer.
- Worth.* Squint. Pages 168-204.
- Eberhardt.* Dynamics and Economics of the Binocular Functions. Optical Journal 1916 and 1917.
- Sheard.* Dynamic Skiametry. Keystone Magazine, 1916 and 1917.
- Hansell and Reber.* Ocular Muscles. Pages 75-123.
- Stevens.* The Motor Apparatus of the Eye. Pages 214-306.
- Thorington.* Prisms—Their Use and Equivalents.

CHAPTER II.

Various Subjective Dynamic Methods of Investigating Convergence as Associated With Accommodation, Fusional Convergence, and Their Importance.

PHYSIOLOGIC EXOPHORIA AND FUSION CONVERGENCE.

The efforts of convergence and accommodation are intimately intersusceptible, so that the smallest impulse to either makes a difference in the other, although the amount is not necessarily equal in the two cases. *von Graefe*, *Maddox* and *Worth* have made rather extensive investigations upon *tonic*, *accommodative* and *fusion* convergences. These investigations have been supplemented by *Howe*, *Theobald*, *Eberhardt*, the *writer* and others. The fundamental conclusions obtained from these researches indicate that "if one eye be covered while the other is fixing a near object, the occluded eye will, in the majority of persons who are neither hypermetropic nor presbyopic, deviate outwards 3° to 4° ." Normally, therefore, we should not expect binocular single vision to be obtained except through the supply of some three or four degrees of fusion convergence from a source or center wholly independent of the accommodation which should not be called into play in distant vision. *Maddox* by means of his tangent scale (in America known, in a modified form, as the *Stevenson's Muscle Test*)—carrying an arrow at the center of a scale graduated to both the right and left thereof and made visually double by the use of prisms base up and down before each eye respectively, the tests being made at 25 centimeters—

concluded that there was a physiologic exophoria at the 10 inch point of about 3° to 5° , measurable and corrigible (to place the arrows vertically, one above the other) by the use of prisms base in. A modified form of this device, due essentially to *Eberhardt*, for near-testing is shown in Figure 26 and will be briefly discussed in connection therewith. This divergence (physiologic exophoria) does not exist in ordinary vision since it is overcome by a visual reflex action, or *fusion reflex*, which affords binocular single vision.

Hence, the exophoria revealed by such tests shows that the association of convergence with accommodation is not complete centrally and, therefore, since the involuntary desire is to fuse two images into one, supplementary action is needed. The additional convergence supply comes through the medium of *fusion convergence*, a function entirely separate from the convergence as associated with accommodation.

We have diagrammed in Figure 22 (taken from *Maddox's* "The Clinical Use of Prisms") the three grades of convergence in vision at 10 inches. These kinds of convergence are *tonic*, *accommodative* and *reflex*.

TONIC CONVERGENCE.

This has been marked in Figure 22 with a question mark (?), since it may be positive, nil, or negative. The various methods of testing tonicity at 20 feet have been discussed in Chapter I. Exophoria in distant vision indicates a deficiency and esophoria an excess of tonic convergence. This *excess* of convergence may occur after prolonged near work, in myopes who hold their work very near the eyes and yet maintain

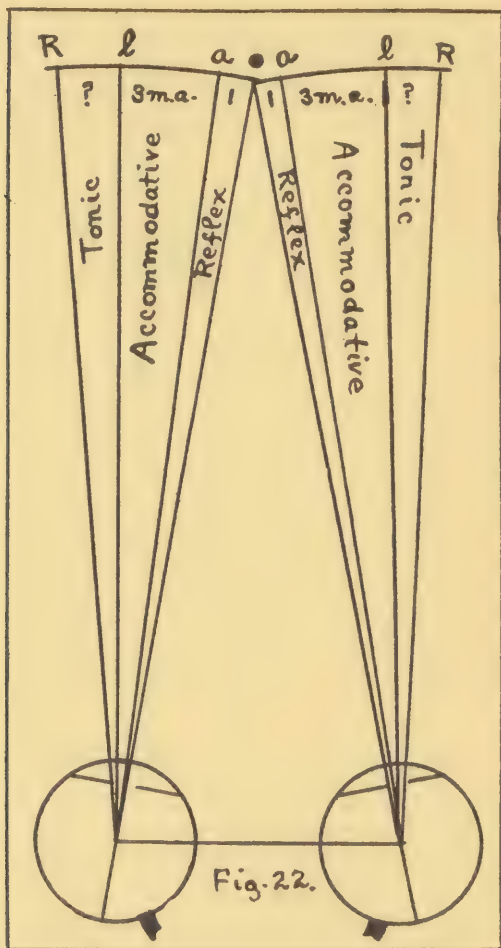


Figure 22. Illustrating the Three Grades of Convergence in Vision at Ten Inches. (From Maddox.)

binocular fixation, and in most hyperopes, particularly when uncorrected. It may readily cause asthenopia. *Deficiency* of tonic convergence may be due to lack of muscular and nerve tone and is quite commonly found in myopia.

ACCOMMODATIVE CONVERGENCE.

In distant vision, when the accommodation is fully relieved, two kinds of convergence only are involved, namely the tonic and the reflex. In near vision, however, there is also the accommodative convergence. For we know that an occluded eye will deviate inward when its mate changes its gaze from far to near points. "As a rule," says *Maddox*, "each diopter of accommodation is accompanied by about three-quarters of a meter-angle of associated convergence, so that in a typical emmetrope, not presbyopic, the 4 D. of accommodation in exercise for vision at a quarter of a meter, are accompanied by 3 m. a. of convergence, leaving a deficit of 1 m. a. to be made up reflexly" as shown in Figure 22. We may make our calculations exact by means of the *Prentice* rule: "Read the patient's inter-pupillary distance in centimeters, when one-half of it will indicate the prism-dioptries required to substitute one meter-angle for each eye." If we, then, assume a case of P. D. 60 mms., and take the accommodative—convergence basis laid down by *Maddox* as correct, our calculations would indicate that, in order that there be binocular single vision at one-third of a meter, approximately 18 prism-dioptries of convergence are required and hence there should be demanded and delivered $18 \times \frac{3}{4}$, or 13° ,

62 ACCOMMODATIVE AND FUSION CONVERGENCE.

of convergence as associated with accommodation, leaving 5° to be fusional or reflexly supplied.

Certain ocular conditions will *increase* the amount of accommodative convergence. They are:—(1) Cycloplegia from any cause, thus rendering the ciliary muscle less responsive to its innervations, demanding increased impulse to accommodation and thereby a proportionate increase of accommodative convergence. (2) If the object fixed be approached to the punctum proximum of accommodation, the effect produced in the lens is less than the impulse, so that the associated convergence produces an esophoria. (3) In hyperopia, without correction, the accommodative convergence is generally greater than under emmetropic conditions.

The conditions which lessen accommodative convergence may be summed up in the one statement that anything which renders accommodation easier (where 1 D of innervation produces more than 1 D of lenticular change) or any condition which demands less than the normal accommodative effort for any specified fixation point (myopia) will lessen the accompanying accommodative convergence.

FUSION CONVERGENCE.

Since objects are seen single up to the punctum proximum of convergence and since tonicity tests prove to us that there may be a divergent or convergent excess and the best experimentations by authorities upon these topics indicate that the association of convergence with accommodation is not complete centrally, there must be a fusion or reflex supplementary convergence operative in the interests of single vision.

We should expect, therefore, that fusion convergence would involve a greater waste of energy in the processes of coordination than the accommodative convergence which is associated with the act of accommodation. The fusion convergence at any fixation point is measured by prisms, base out, in testing the maximum of positive convergence and prisms, base in, in testing the maximum of negative or divergent fusion, the patient viewing an object such as a line of type. We quote the following paragraph from *Maddox*. "The following table shows the fusion range found for varying distances in a man 32 with normal refraction * * *. The first column (A) gives the refracting angle of the highest (+), base out, and (—), base in, prism he can overcome at the various distances. The second column (D) shows the deviation of *each* eye produced by the aforesaid prisms; it is found by calculating the deviating angle of each prism, and dividing it between the two eyes * * *. The third column (R) gives the fusion range for each eye calculated from the figures in column (D). It will be noticed that both

	(A) Single Prism	(D) Deflection of each axis	(R) Fusion Range
.6 m.	16° : — 3°	4.5° : —0.75°	5.25°
.1 m.	18° : — 8°	5.° : —2.°	7.°
0.5 m.	20° : —12°	5.5° : —3.75°	8.75°
0.33 m.	24° : —16°	6.75° : —4.5°	11.25°
0.25 m.	30° : —18°	9.° : —5.°	14.°

the positive and negative parts of the range increase as vision becomes nearer; also that the positive part exceeds the negative, though less so as vision becomes nearer."

The fusion convergence is the element most affected by ocular fatigue. We find it involved in so called

periodic squint. No squint may appear in the morning but as the labors of the day go on, especially if this involves much close application of the eyes, the vigor of the visual reflex diminishes until the amplitude of the reflex becomes less than the squint. If the patient is a hyperope with excessive convergent tonicity and accommodative convergence it is entirely possible that the negative reflex convergence will be able to master it in the early hours of the day, but as the excessive strain is withstood hour after hour the effort will be abandoned, although there may be no squint at distance since the demands upon the fusion convergence are lessened at that point.

CLINICAL METHODS OF TESTING THE ACCOMMODATIVE
CONVERGENCE AND THE RESERVE FUSION CON-
VERGENCE AT THIRTEEN INCHES.

Figures 23 and 26 show the forms of two varieties of test line which may be used for the testing of the convergence as associated with accommodation at any near point. We insert these cards in the carrier provided with the phoro-optometer and sliding upon the rod thereof, or else have the patient hold the card at the desired distance from the eyes. This distance should preferably be that at which the patient's daily close work (occupation and reading distance) is done and for which lenticular assistance is chiefly required. Invariably, unless there is a reason to the contrary, we make the test at thirteen inches.

One very important feature about these test objects is that each shall carry a *printed line of type* with an accompanying indicator point such as the black circle in Figure 23 or the arrow in Figure 26. In the ori-

ginal *von Graefe* test object, of which the forms now presented are but modifications, a single dot or a ruled line only was used. *Worth* (Squint, page 177) presents an acceptable form of test card carrying ten letters of "pearl" type having a large capital O in the middle. He likewise recommends the use of a card 2 feet square in order that the object shall be seen in the center of a blank field with no edges near to elicit fusion. In this respect the large size of card recommended may be superior to those used by us which have a size of about 5 x 6 inches. *The purpose of the line of letters is to bring into play the accommodation*, the evidence that such is the case being furnished the practitioner by having the patient read the letters or words. The viewing of a ruled line is an indefinite criterion. Hence, the two essential requisites in the accommodative convergence tests are: (1) the accommodation must be active and (2) the fusion convergence and anything which stimulates such a visual reflex must be annulled.

THE DOT AND LINE TEST CARD.

Figure 23 shows the form of test objects in which a heavy dot and line of type are employed. The *Mad-dox* double prism, consisting of two prisms each of 4° ground base to base, is inserted before one eye, the patient wearing the full binocular distance correction as previously determined upon. The wearing of the distance correction is essential as we are desirous of knowing whether such corrections are compatible with, or in harmony with, the proper co-ordination of ocular functions. The double prism being inserted with base line horizontal before one eye, its mate being

occluded, the position of the prism is so adjusted that the two dots as produced by this device are seen in an

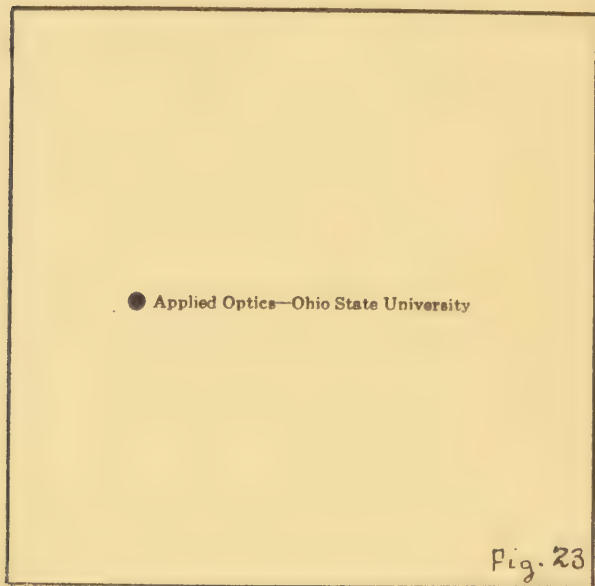


Figure 23. Dot and Line Test Object for Use in the Accommodative Convergence Test.

apparently exact vertical line. We use the word "apparent" since the writer has found by making use of a considerable number of such prisms that the base line of the prisms has to be invariably tilted slightly downward temporally or upward nasally before the dots appear in a vertical row. A research upon this problem has been in progress for some time; we have found that there is some difference in the results dependent upon whether the card is held in the pri-

mary position or somewhat as in the general position usually assumed in reading and have concluded that there is sound physiologic proof of a slight nasal extorsion above or intorsion below when convergence is in vogue. When, therefore, the two dots have been *aligned* vertically, the occluded eye is uncovered, when three dots and lines of type (we use No. 2 or No. 3 Jaeger type for the printed line) should be seen normally. The relative positions of these three dots, i. e. the position of the middle dot with respect to the first and third, constitutes the basis of our test upon the accommodative convergence. To be more specific: we generally insert the double prism before the left eye. The upper and lower lines of Figure 24 will

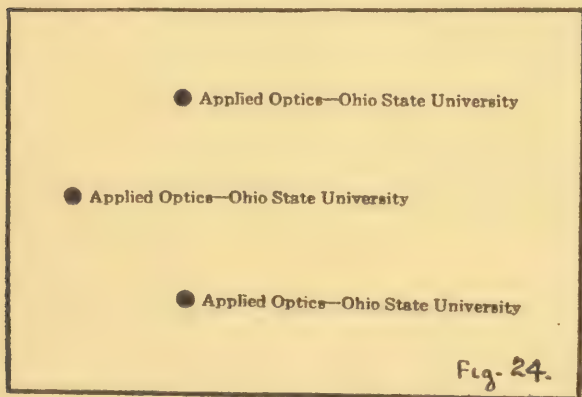


Figure 24. Images as Seen under Fusional Dissociation Using the Maddox Double Prism.

then be seen by this (left) eye. The middle line is seen by the right eye; the location of the middle dot while the line of type is being read gives the clue to

the convergence as associated with accommodation. Suppose the middle dot is to the left of the upper and lower ones; we then have an ocular condition of exophoria indicated since the images are crossed and, therefore, according to the law of projection, that which is received upon the retina to the temporal side of the macula is projected into space to the nasal side and so on. Suppose that the patient reports that the middle dot is toward his left eye and that we find that it takes 6° prism, base *in*, to bring the three dots in alignment as nearly as possible. We conclude, then, that there are six prism dioptries (i. e. actually 3°) of physiologic exophoria. The question is, how much convergence is associated with the accommodation? Taking the average interpupillary distance of 64 mms., with fixation at thirteen inches or one-third of a meter and applying the *Prentice* rule, we find that 19 prism dioptries are required for binocular single vision at this distance. Since our assumed results on accommodative convergence have shown 6 prism dioptries of exophoria at this same point we conclude that the accommodative convergence amounts to 13 prism dioptries. This is about as it should be under normal conditions, since about two-thirds of the total convergence impulse is supplied by, or associated with, the accommodation. If it takes more than 6° prism, base *in*, to align the dots we should conclude that there was insufficient accommodative convergence (generally found associated with myopia) and if the dots are initially in a row or the middle dot is displaced on the same side as the 'unprismed' eye we should conclude that there was an oversupply of accommodative con-

vergence and hence generally an abnormal demand upon the accommodation. Each case, however, must be taken upon its own merits and in the light of the remaining data obtained during an examination.

Hyperphoric Conditions. Two additional tests which are of importance in the study of the conditions of poise of a pair of eyes are made possible under the procedure just described. These are: (a) examinations upon the vertical equipoise and (b) cyclophoria at near points. If there is a condition of vertical orthophoria the middle line will appear centered with respect to the other two lines providing the double prism is properly placed before one eye and the two prisms composing the testing piece are equal in power. The test for vertical orthophoria should be made while there is before one eye that prism which aligns the three dots vertically. The amount of prism, base up or down, needed to place the second line midway between the first and third denotes the amount of hyperphoria or cataphoria present. The eye which does not wear the double prism is the one under test. When both distant and near-point investigations show a degree or more of vertical imbalance, at least a partial correction for the same should in general be given. It is an open question as to the procedure when there is no hyperphoria or cataphoria at 20 feet and when there is an appreciable amount thereof at the reading point. In presbyopic corrections the writer generally incorporates some optical assistance in the reading correction looking to the alleviation of such an heterophoric condition.

Cyclophoric Conditions. The patient should be asked the question as to whether or not the three lines are parallel. We believe that this test should be made with the distance correction (or reading correction in cases of presbyopia) before the eyes in addition to such prism assistance as will establish strictly orthophoric conditions at the reading point. There are cases in which a cyclophoria will disappear or be materially lessened when heterophoric corrections are given. These must be indicative of mal-attachments of the straight muscles involved. Such a statement as this is not contrary to the correct teaching that a cyclophoria *per se* — in which the oblique muscles are involved as in cases of oblique astigmatism with diverging or converging axes—cannot be relieved by prismatic correction but only by cylinders (vide *Savage's* "Ophthalmic Myology" and "Neuro-Myology").

In making the cyclophoric tests at the reading point, the double prism may be inserted before the left eye. The middle line is then seen by the right eye, which is under test. If all three lines are parallel no cyclophoria is indicated. If the middle line occupies the relative position shown in Figure 25 (A), in which the middle line dips toward the nose, a weakness of the right superior oblique, or right plus cyclophoria, is indicated. In Figure 25 (B) there is diagrammed the positions of the lines when the middle line dips toward the temporal side showing right minus cyclophoria or weakness of the right inferior oblique muscle. The writer believes that, in general, these tests at near are of little value unless taken in conjunction with tests conducted with fixation at twenty feet (see *DeZeng's* "Modern Phorometer",

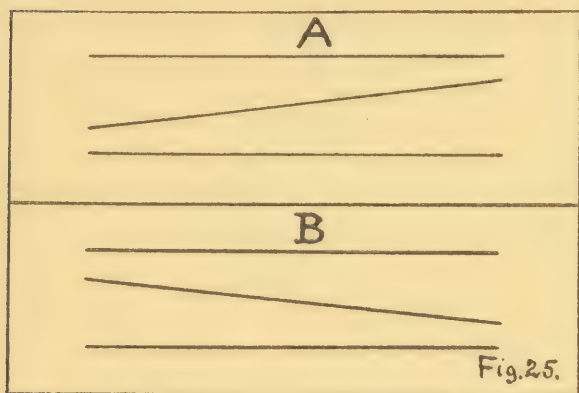


Figure 25. Illustrative of Cyclophoric Tests.

pages 47-50). The procedure at distance involves the use of two Maddox rods so placed as to give two horizontal streaks when an 8° prism, base up or down, is inserted before the eye under test.

In making the test for cyclophoria at the reading point using the double prism method we have found the conditions diagrammed in Figure 25 (A) of almost universal occurrence. Tests upon subjects, such as engineering students, whose statements are reasonably certain of being trustworthy, indicate about 3° to 5° tilting when examined at the reading point. We have come, therefore, to regard this condition as practically physiologic and the normal condition of affairs when accommodation and convergence, with some subvergence in general, are exercised. As a result we give little heed to small amounts of apparent plus cyclophoria but make careful investigations upon the obliques when minus cyclophoria is apparently indicated.

THE LINE AND ARROW TEST CARD.

Figure 26 shows a form of test line carrying a subjoined arrow. In practice a card, bearing these symbols, is used in the manner and at the distance stated in connection with the Dot and Line Test. To produce duplicity of images there is ordinarily used a 4°

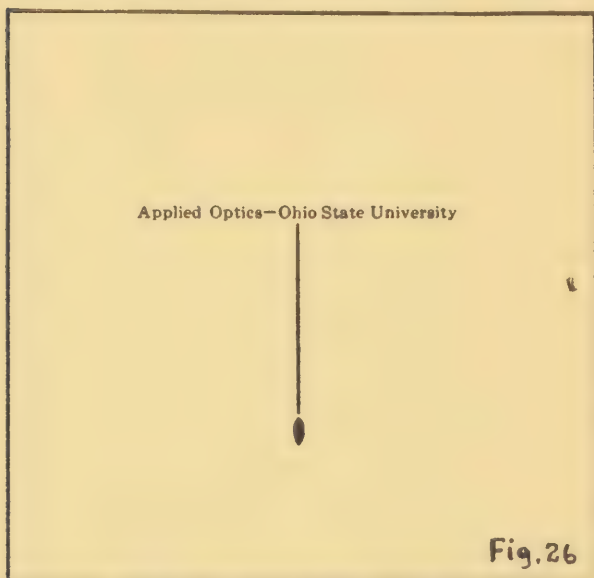


Figure 26. Line and Arrow Test Object for Use in the Accommodative Convergence Test.

prism, base down, in front of one eye and a like prism, but with base up, before the other eye. The two images of the test object will be seen in space displaced toward the apices of the prisms or away from the base. That is, if one prism is placed base down before the

right eye, the upper of the two space images will be that viewed by the right eye, and so on. This arrangement of affairs, exhibiting the normal accommodative exophoria, is shown in Figure 27.

This form of test object is a modification of the *Maddox* Tangent Scale with subjoined arrow or of the *Stevenson* Near Muscle Test. We are positive, however, that the results as obtained by these and similar devices are inaccurate as a general rule in the data which they furnish, for the reason that the head

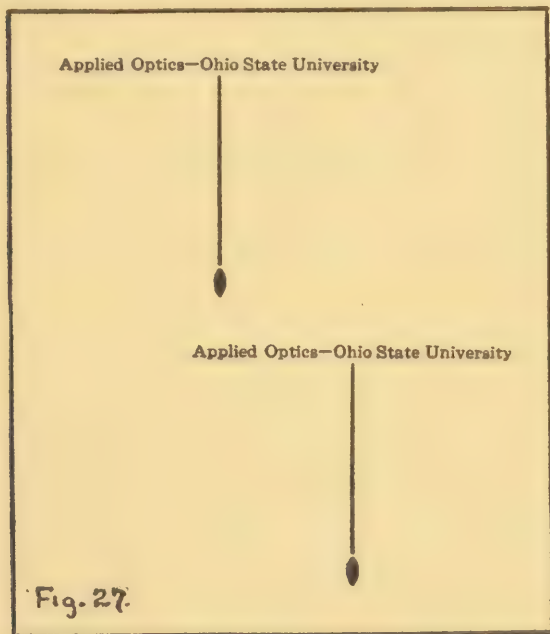


Figure 27. Duplicity of Images under Fusional Dissociation by Prisms Base Up and Down before each Eye respectively.

of one arrow and the tip of the other fall within the fusion areas of the eyes and that fusion is thereby stimulated. This is certainly true if the fusion area measurements of *Savage* are correct and there is every reason to believe that his investigations upon this matter are substantiated. How often has the writer had the person under this test say: "Why, I can bring the arrows over each other or not to suit myself." The explanation cannot lie in the presence or absence of accommodation and hence of accommodative convergence since the varying effects can be obtained when accommodation is uniformly enforced. The results (as yet unpublished) upon about five hundred subjects using the two methods—(a) dot and line and double prism and (b) line and arrow and prisms base up and down respectively before each eye—show a greater degree of exophoria as well as a greater degree of esophoria by the first method than by the second. The great criterion in all tonicity and accommodative convergence tests is that *fusion must be passive*, i. e. one set of images must fall *in toto* outside of the fusion area.

FUSION CONVERGENCE.

We have discussed the fusion range in near vision in some detail in previous paragraphs of this chapter, and have commented upon the method of measuring the negative or divergent fusion by prisms, base in, and the positive or convergent fusion by prisms, base out, at near points. The table which we quoted from *Maddox* and which is, we believe, in a general way representative of the trend of the convergences at various points, clearly demonstrates that both positive

and negative convergences increase in value as the fixation point is approached to the eyes. It is, therefore, evident that a distinction should be made between tests for distant vision, which normally involve practical parallelism of the visual lines and no accommodation, and tests for near vision where the visual axes converge to begin with and in which accommodation is involved. The writer believes from some experimentation he has been carrying on that the convergence as associated with accommodation becomes greater (i. e. there is proportionately less physiologic exophoria) as the accommodative demands are increased with approach of the fixation object by virtue of the fact that the innervation required to produce the last diopter of accommodation is somewhat greater than that required for the first diopter, hence giving increased accommodative convergence and alleviating the demands upon the fusion convergence, thereby indicating greater fusion convergence reserves at points closer to the eyes.

Figure 28 shows the form of test object which we use in fusion convergence (positive or negative) measurements at the reading point. It consists of a small card printed with a vertical row of letters set in about 12 point type. This is handed the patient and the question asked as to whether one line only is seen. The answer will invariably be in the affirmative; if it is not, we are at once informed of the existence of diplopia at near points which will doubtless have been reported by the patient or else discovered by the examiner in his distance tests. The examiner then turns in slowly prism power until the maximum power

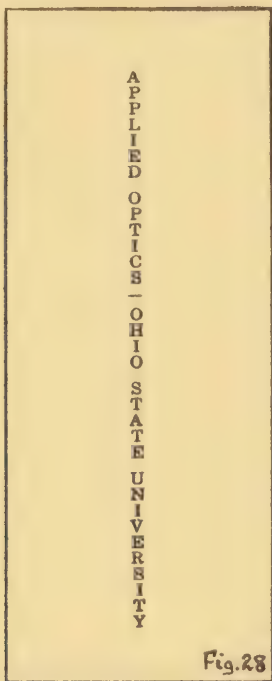


Figure 28. Test Line for Finding the Amounts of Fusion Convergence Reserve at Near Points.

base out is obtained through which a singleness of line of type can just be maintained. In general, the positive portion only is tested through the medium of prisms base out. Wisdom in these tests seems to lie in a testing of the positive fusion convergence when tonic exophoria at distance and excessive physiologic exophoria, as associated with accommodation, are evidenced at the reading point, whereas the negative por-

tion should be tried out in cases of high tonic esophoria and excessive accommodative convergence.

Such investigations as those we have been describing test, in reality, the *reserve* of fusion convergence. The criterion or basis for comfortable vision is taken as that laid down by *Landolt* in which he says that not more than one-third or one-fourth of the fusion range (amplitude) of convergence can be continuously in exercise for comfortable vision. If a line is seen single at the thirteen inch point we are then aware that the fusion convergence has been able reflexly to take care of the deficiency (positive or negative) of tonic or accommodative convergence. The adducting or abducting prisms which can then be added before a pair of eyes, with fixation constant, is a measure of the *reserve convergence*. If our premises as to accommodative convergence and reflex convergence are correct, the problem becomes one of simple arithmetic in any case as far as data is concerned. What to do in the nature of prismatic corrections, prismatic and other training exercises, lenticular refractive corrections and so forth is probably the most difficult problem in refraction. Let us assume for illustrative purposes two simple cases. Suppose that tests demonstrate a tonic exophoria of 5° and an accommodative-convergence deficiency of 16° of which, allowing 5° for the normal physiologic exophoria, 11° represents the genuine accommodative-convergence deficiency. We are then entitled, we believe, to say that the true accommodative convergence is only 6° , allowing 5° for the tonic exophoria. However, at least 16° of reflex or fusion convergence is demanded in binocular

single vision at thirteen inches, while the total demand fusionally (including the tonic) and accommodatively is about 23° . Let us further assume that the positive fusion reserve at thirteen inches is 20° . This means, therefore, a total positive convergence amplitude of 43° of which 16° is demanded reflexly. Vision at near points under such circumstances is likely to be uncomfortable if engaged in for any length of time. As a second case let us assume a tonic esophoria of 5° , an accommodative convergence of 5° (i. e. 5° over and above the physiologic exophoria), and a positive reverse convergence of 25° and a negative reserve convergence of 12° . The drain will not, then, be upon the positive fusion convergence but upon the negative convergence which shows a total fusional amplitude of 18° of which 5° is demanded. This it is normally able to bear. But the assumed data indicates that the accommodative convergence is excessive in addition to the initial esophoria indicating that the accommodative demands need attention.

The writer agrees with *Maddox* when he says that the view that all squints are due to central fusion defects *only* is untenable. "Were it true, all squints would date from birth, whereas it is a matter of common knowledge that a very large proportion date from the age of three years, after binocular vision has been enjoyed for some time. Moreover, they generally commence in near vision only, or when the attention is concentrated upon an object." The faculty of fusion divergence is not sufficiently developed to conquer the strong impulse to convergence which accompanies the excessive accommodative impulse in hyperopia.

THE GREAT OCULAR PROBLEM—THE ECONOMIC CO-ORDINATION OF ACCOMMODATION, ACCOMMODATIVE CONVERGENCE AND FUSION CONVERGENCE.

The above caption expresses the view that we have been dealing in this chapter with the most vital problem in the economy of the ocular regime. When shall prisms be prescribed and when not? When are prismatic or natural exercise likely to be of any avail? When should maximum or minimum convex or concave lenses be prescribed? When is operative interference necessary? It would take a volume to answer these questions: still they would not be solved. In brief, we state the following answers. *Anatomical defects can be altered* by operative interference, the *tonic* position by prisms, the *accommodative* convergence by lenses and the *fusion* convergence by any of these. The *tonicity* may be, however, and generally is, associated with accommodative defects and the results under proper refractive corrections should be tried and time allowed for a re-adjustment before the insertion of prisms in the prescription. Suppression or stimulation of the accommodation, and thereby the associated accommodative convergence, should be indulged in whenever various tests upon the accommodative resources, fusion convergence and so on show that the function of accommodation is operating under conditions in which the effort is disproportionate to the work. In this group fall accommodative squints and cases in which the squint appears only in near vision. Prisms can be of no service in the correction of such conditions as these *per se*. Of necessity the burden in binocular single vision must fall upon the negative

fusion convergence and this may be temporarily aided, if deemed best, by the use of prisms base out. The writer, however, does not believe in the use of prisms for permanent wear in persons *under forty* except as a last resort. The *fusion convergence* may be altered by operation, lenses, or prisms. If the proper accommodation-convergence relations can be re-established it will be found that, very frequently, the problem will be solved. Attempts at training the fusion convergence, particularly a weak positive fusion, should always be made in persons under thirty-five to forty. The simple 'finger toward the nose' exercise over a period of some weeks will work marvels in many cases; we give an illustrative example in Case 10. The difficult problems are those in which the accommodative needs, for example, demand that convex lenses be prescribed while all the accommodative convergence and fusion convergence tests (in particular) show that the reflex convergence is low. In such cases we are prone to give corrections involving proper lenticular assistance coupled with low prisms (1° to 1.5°) base in over each eye. The writer feels that prisms base *in*, when indicated, are of much greater ocular service than are prisms base *out* when prescribed. As a general rule prism and other exercises are of little avail in persons of middle-age and beyond, hence these very important tests should be made and great nicety of judgment exercised in the correction given when low fusion convergence reserves are found at the reading point.

In concluding this all too brief presentation of this very important subject we cite some of the essential features of three extremely interesting cases.

ILLUSTRATIVE CASES.

Case 8. Hyperopia with Periodic Squint. Mr. S. G. Aet. 21 years. Has frontal and temporal headaches; eyes sore and burn; print blurs "when he reads in a certain way" (probably binocularly); has had diphtheria and scarlet fever. *Static retinoscopic* tests showed O. D. -0.25 D. S. $\ominus +.50$ ax. 90, O. S. -0.50 D. S. $\ominus +.37$ ax. 90. *Dynamic skiametry* evidenced at thirteen inches O. D. $+1.75 \ominus +.50$ ax. 90 and O. S. $+1.37 \ominus +.50$ ax. 90. *Subjectively*, O. D. $-.37$ D. S. $\ominus +.50$ ax. 90 and O. S. $-.50$ D. S. $\ominus +.37$ ax. 90, each eye equally good, did not give better than $V=8/10$ monocularly or $V=20/20$ with difficulty binocularly. With these corrections the patient's *muscular equipoise* at 20 feet showed, under the binocular tonicity test, 8° of esophoria; cover test, either eye, showed a redress of about 1 mm. out. Monocular tonicity tests disclosed that the major portions of the esophoric tendencies resided in the left eye. The *accommodative-convergence* tests evidenced 15° of esophoria (over and above the allowance for the 6° of physiologic exophoria). The various subjective *accommodation* tests at 13 inches evidenced about 9 D. for each eye. The *negative fusion convergence* reserve at 13 inches was 6° or relatively nil. The *duction tests* at 20 feet evidenced, for each eye, the following: abduction 3° , adduction 30° . Our analysis of the case is that there is marked evidence of (1) anatomical defect, (2) excessive accommodative convergence, (3) insufficient negative fusion reserve. We prescribed the following:—(1) medical examination and assistance, (2) abduction exercise recommended by Thorington ("Methods of Refraction," pages 275-

277), (3) reading correction: O. D. $+1.25$ D. S. $\ominus +.50$ ax. $90 \ominus 1.5^\circ$ base out and O. S. $+1.12$ D. S. $\ominus +.37$ ax. $90 \ominus 2^\circ$ base out, (4) distance correction, O. U. $+1.37$ ax. $90 \ominus 1.5^\circ$ base out giving $V=8/10$ (initially more unsatisfactory to patient than no cylindrical correction). The patient reports perfect ocular comfort over a period of six months. We expect to increase the distance correction as soon as feasible.

Case 9. Excessive Accommodative Convergence. This case is typical of a set of ocular conditions which is occasionally found in practice, in which there is apparently either no refractive correction for distance or such a weak-powered sphere as to be negligible, but in which assistance is demanded when reading and working at the usual distance are engaged in. The young man in question is a university student, twenty-one years of age, a student of law and accustomed to long hours of close application to his books. He reported no symptoms other than an apparent fatigue of his eyes. The *static skiascopic* examination revealed a neutral shadow condition and at times a slightly myopic motion; no convex lenses could be added without producing a decided reversal of shadow. *Subjectively* no distance correction was found; monocularly a quarter of a diopter convex lens was rejected as making the twenty foot line unreadable; binocularly this line was readable through quarter diopter convex spheres. The *dynamic skiametric* findings with observation and fixation at thirteen inches showed a decidedly "with" motion and $+1.25$ D. S. before each eye was needed in order to produce neutrality. The *duction* tests at twenty feet showed abduction 7° , adduction 20° , superduction 2° and infraduction 2° , indi-

cating normal duccion or fusion powers at the distance for which the test was made. The *Maddox* rod test at twenty feet evidenced no muscular imbalance. But the *accommodative tests at the reading point*, using 4° prisms base up and down before each eye respectively and the line and arrow card, showed the arrows directly over each other, indicating about 6° of esophoria, while the double prism and dot test showed 10° of esophoria with no vertical imbalance or cyclophoria at near. The *accommodative amplitude* was determined as 8 D. for each eye by the concave lens method of testing this function at thirteen inches. This young man was given O. U. $+1$ D. S. for reading, wholly in the interest of the proper correlation of accommodation and convergence at the reading point. It may be pointed out with profit that if the practitioner had depended solely upon the distance objective and subjective findings and upon determining the amplitude of accommodation by the method commonly in vogue, i. e., the distance from the eye at which No. 2 Jaeger type can be read both monocularly and binocularly, he would have been logically forced to conclude that these eyes needed no assistance; but determinations by dynamic skiametry and by investigating the conditions at the reading point with accommodation active, fusional convergence passive but accommodative convergence active, clearly indicated the need of lenticular assistance and the *reason why*.

Case 10. Weak Positive Convergence. This extremely interesting case of actual excessive accommodation with a low degree of astigmatism is presented in some detail as it illustrates that condition of affairs, only too frequently found, in which the patient

was wearing minus cylinders at axis 180° when plus cylinders at axis 90° were really demanded and ultimately accepted. In this connection read *Howe*, "Muscles of the Eye," Vol. II, page 26, *et seq.* Young lady under description came complaining of nausea, headaches and inability to do close work with any comfort. She had typhoid fever five years ago and trouble dates from that time according to her statement. A preliminary ophthalmoscopic examination showed congestion or hyperesthesia of the retina. The general appearance of the patient was anemic. She was put under competent medical treatment at once. The ocular examination evidenced the following results at the first examination. *Static retinoscopy*, O. U. -0.25 D. S. $\ominus -0.75$ cyl. ax. 180 . *Subjectively* this could be made O. U. -0.75 cyl. ax. 180 with slightly blurred distant vision ($V=8/10$). *Dynamic skiametric* tests were very erratic but indicated in general O. U. $+0.75$ cyl. ax. 90 . Such a result with dynamic skiametry is frequently to be looked for, since the method generally indicates increased convex lens power as compared with the static skiascopic findings. The *tonicity tests* indicated orthophoric conditions. The *accommodative convergence*, wearing the distance corrections, evidenced 4° of over-stimulation. The *accommodative* tests indicated 9 D. for each eye by the concave-at-near method. The *positive fusion convergence reserve* was not in excess of 6° . In fact, as a pencil was approached toward the young lady's eyes, she winced and exclaimed: "Do not do that again; it makes me sick." The cause of the inability to do near work and the general cause of the ocular discomfort therefor resided in this weak fusional convergence. We examined the correction she was wearing, prescribed about two years

previously under a cycloplegic according to her statement, and found that they exactly incorporated our static findings which, by the bye, the writer was certain were incorrect. We instituted prismatic exercises and had the patient carry out the 'finger toward the nose' exercise for a period of a week. *Dynamic* tests then evidenced O. U. $+1.00$ D. S. $\ominus -0.75$ cyl. ax. 180. Subjectively we were able to force on by degrees O. D. $+0.87$ D. S. $\ominus -0.75$ cyl. ax. 180 and O. S. $+0.50$ D. S. $\ominus -0.75$ cyl. ax. 180, giving equal visual acuity and binocularly affording the patient $V=8/10$. The patient was given O. U. $+.62$ cyl. ax. 90 and the exercises continued for a period of two months, when the reserve fusion convergence at 13 inches tested up to 20° . At the present writing she is wearing O. D. $+.37$ D. S. $\ominus +.75$ cyl. ax. 90 and O. S. $+.25$ D. S. $\ominus +.62$ cyl. ax. 90. Tests show no tonic errors at distance, proper co-ordination between accommodation and convergence and plentiful fusion convergence. She has relief from the symptoms of which complaint was made.

REFERENCES.

- Maddox*—The Clinical Use of Prisms. Pages 72-100 and 158-178. Ocular Muscles. Pages 91-98.
Worth—Squint. Pages 176-186.
Prentice—Ophthalmic Lenses and Prisms. Pages 50-58.
Thorington—Methods of Refraction. Pages 266-290.
Eberhardt—Dynamics and Economics of the Binocular Function. (Optical Journal, 1916 and 1917).
Sheard—Dynamic Skiametry. (Keystone Magazine, 1916 and 1917).
Howe—Muscles of the Eye. Vol. II.
Hansell and Reber—Ocular Muscles.

CHAPTER III.

A Resume of Present Day Methods of Investigating the Accommodative Range and Amplitude.

There are two principles or methods of procedure in common use, which are in theory essentially identical, for the determination of the dynamic refraction. For we either seek the *location of the near point* and measure its distance from the eye and take the inverse of this quantity (expressed as diopters) to represent the total dynamic refraction or else we determine upon *that lens whose refractive power* equals that of the eye at its maximum of accommodation.

DETERMINATION OF THE SITUATION OF THE NEAR POINT AND THEREBY THE ACCOMMODATIVE AMPLITUDE.

The common method in vogue is to provide the eye under test—this being a monocular procedure—with that refractive correction which establishes as nearly normal acuity at distance as possible and to then approach the test card carrying No. 2 Jaeger type ($V=0.5\text{ D}$) until the nearest point is reached at which it can still be read or, in other words, until it commences to become indistinct. A measurement of this shortest distance from the cornea is commonly taken as the punctum proximum (abbreviated P. P.) or near point. If the distance ametropic correction is inserted before the patient's eye and this affords normal acuity, the eye is rendered artificially and manifestly emmetropic and the near point determination, if one accepts the validity of this method, gives the true amplitude of accommodation under the condi-

tions of the test and obviates the arithmetical calculations involved in the formula $A=P-R$. In this expression A represents the amplitude of accommodation, P the near point in equivalent diopters and R the far point in equivalent diopters. The distance correction, especially if it includes *cylinders*, should always be inserted before making these tests; by this we mean to insist upon the insertion of the proper cylindrical correction in all methods of testing accommodative range and amplitude.

Inaccurate accommodative amplitudes from near point determinations are due, we believe, chiefly to the following factors:—(1) there is a more rapid increase of the visual angle under which the test object is seen than of the circles of diffusion, hence the size of the retinal image increases as the test type is approached to the eye and these diffused but larger retinal images are more easily interpreted mentally than are smaller but sharper images; therefore, the person under test is able to read at a point nearer than that at which accommodation is proportionately enforced: (2) the reduction in the size of the pupil, which normally occurs upon the approach of an object to an eye and which thereby reduces the sizes of the diffusion circles: (3) the effect of closing the lids and thus narrowing the palpebral fissure; this narrowing of the pupillary opening by a narrowing of the palpebral fissure is equivalent in action to a stenopaic slit and is particularly potent and active in high astigmatism, and (4) the size of the test-type or line object must bear a certain relation to the visual acuteness of the eye under examination: experimentation by objec-

tive methods to be disclosed in the succeeding chapter shows that there are persons who possess a good range of accommodation who cannot read (or *will not* read) fairly fine print at any distance and, again, there are those who are able to read such print over a wide range whose accommodative amplitude is objectively shown to be relatively depleted.

The reader will, therefore, be appreciative of the fact that the writer has never been enthusiastic about the value of near point determinations as ordinarily made with a tape measure and a few lines of test type. And this, in particular, for the reason that our near test-cards are printed in fonts of printers' type and in nowise observe the scientific standard of a five-minute-angle for the distance specified at which the reading should be done.

DETERMINATION OF THE ACCOMMODATIVE AMPLITUDE
BY ASCERTAINING THE LENS WHOSE REFRACTIVE
POWER EQUALS THAT OF THE EYE AT ITS MAX-
IMUM ACCOMMODATION, THE TEST BEING
MADE MONOCULARLY AT TWENTY
FEET.

This test is based upon the fundamental principle that for a person whose punctum proximum is situated at a finite distance, it amounts to the same thing whether he looks at an infinitely distant object through a concave lens or without such a lens at an object situated at a distance equal to the focal length of the lens used. In theory, then, all we need to do is to seek the strongest concave lens (equivalent to the difference between the strongest plus and the strongest minus lenses, or weakest minus and strongest minus

lenses, dependent upon the ametropia present) "through which an eye still sees distinctly at a long distance and this lens will give the maximum of *dynamic* refraction of which the eye is susceptible" (*Landolt*). Hence the strongest concave or weakest convex lens through which an eye can see at a distance gives the refraction of that eye when adapted to its punctum proximum. The sign of the lens must be changed since concave indicates positive and convex negative refraction. In practice, then, the patient is provided with the minimum concave and maximum convex lenses, together with the cylinders, which will afford as nearly $V=20/20$ as possible. In this concave—at—distance method the writer usually selects the $V=8/10$ line as a basis for the distinct-distant-vision test.

There are several vital objections to this method of procedure, however. (1) The visual acuteness is considerably diminished by the use of concave lenses which diminish the sizes of the retinal images, (2) the term "*distinct vision at distance*" is indefinite and the size of the standard test-object is uncertain, (3) it is difficult to get an eye to put forth its maximum effort of accommodation when looking at distance, for accommodation is not thus invited as when an object is approached progressively toward an eye, and (4) it is a test upon a function made in a manner which demands that it be brought into play under conditions contrary to those set for it by nature. It is certain that the amplitude of accommodation thus obtained is smaller than that found from near point tests. The reasons are apparent, for the factors, such

as increase in the size of the retinal images which are likely to give pseudo near-points which are too close to the eye, are exactly reversed in their actual physical and physiologic actions when viewing a distant test object through concave lenses. It is probable that an *average* of the two amplitudes as determined by these two methods will afford a fairly correct estimate of the real accommodative amplitude in most cases. Very radical differences do, however, arise in the results of the two methods and these should form most valuable differential and diagnostic data to the practitioner.

DETERMINATION OF THE AMPLITUDE OF ACCOMMODATION BY ASCERTAINING THE LENS WHOSE REFRACTIVE POWER EQUALS THAT OF THE EYE AT ITS MAXIMUM ACCOMMODATION, THE TESTS BEING MADE AT THIRTEEN INCHES.

We shall refer to this method as the *Concave—at—near* procedure. The normal reading point is about twelve to fifteen inches from the eyes; we shall take thirteen inches, equivalent dioptrically to 3 D., as a normal reading distance. A moment's consideration will convince the reader that a very logical procedure in investigating the amplitude of accommodation would be to find its reserve at the reading point and to then add this quantity to the three diopters demanded while reading No. 2 Jaeger at thirteen inches. It should be accepted as a fundamental principle that *any ocular function should be investigated under conditions of activity or quiescence which conform to the philosophy of the particular phase of its activity under consideration*. The normal reading point is at a foot from the eyes; it is logical, therefore, to de-

termine its reserve with respect to the point at which this reserve should hold. The thirteen inch or thirty-three centimeter point should be ordinarily chosen as the point at which the accommodative resources are to be investigated, rather than at a nearer or more remote point, for the reason that nature has ordained the establishment of a comfortable convergence point (leaving two-thirds to three-fourths of the fusional convergence in reserve) and a normal distance of distinct vision at about a foot from the eyes. In passing, let it be stated that we believe that the function of convergence, which normally remains constant in its strength, rather than accommodation, which becomes depleted with age, is the determining factor in the establishment of this normal reading or close work distance.

The method is easily carried out. The test should be made monocularly and before each eye should be placed the distance correction, particularly the cylindrical element. The spherical element should be the maximum convex or minimum concave lens which, either alone or in combination with the cylinder as the case may be, affords $V=20/20$ or as nearly the normal standard as can be obtained. The writer ordinarily uses No. 2 Jaeger type ($V=0.50$ D.) held at thirteen inches; the ciliary must then exert three diopters of accommodative action or, at least, produce three diopters of lenticular action or refractive change if normally acting. Minus spheres, beginning in general with a -1 or -1.5 diopter glass, are then inserted in the trial frame or turned up in the lens battery in connection with the phoro-optometer until the maximum

minus lens has been inserted through which the No. 2 Jaeger is just barely readable. The available amplitude of accommodation as thus obtained is the sum of the three diopters exerted by the accommodative mechanism in order to read at thirteen inches plus the amount of concave lens power overcome and expressed as a positive quantity.

There are certain reasons for the insertion of distance binocular findings when investigating the accommodative resources at the reading point. These are briefly:—(1) The tests upon the total accommodative resources and accommodative reserve are made under conditions imposed upon them by the optical corrections and assistance which the static refractive errors have demanded; we are desirous of knowing whether or not such a correction will fit in with the economic and comfortable operation of accommodation and convergence at near points. (2) The accommodative mechanism has been so aided as to permit of its meeting most advantageously the normal demands made upon it as the fixation point is moved from twenty feet to near points. (3) The practitioner is afforded, when the patient is wearing the binocular distance findings, a ready and safe basis for those modifications which he may desire to incorporate in the prescription that he ultimately gives the patient by virtue of the tests upon the accommodative amplitude and reserve and upon the muscular poise at the reading distance.

Since the effect of concave lenses is to minimize the sizes of retinal images and hence the apparent sizes of the test-objects, it should be expected that

the amplitudes of accommodation as determined by concave—at—near methods would be less than by near-point determination.

We append a table of amplitudes of accommodation as determined by various investigators.

AMPLITUDE OF ACCOMMODATION.

Age	Donders. (Near Point)	Duane. (Near Point) Average	Jackson. (Concave Lenses. Accommodation Associated with Convergence)	Sheard. (Monocular Test Object at 13 in. Concave Lenses)
10	14.	13.5	14.	
15	12.	12.5	12.	11.0
20	10.	11.5	10.	9.0
25	8.5	10.5	9.	7.5
30	7.0	8.9	8.	6.5
35	5.5	7.3	7.0	5.0
40	4.5	5.9	5.5	3.75
45	3.5	3.7	4.	
50	2.5	2.0	2.5	
55	1.75	1.3	1.25	
60	1.00	1.0	0.5	

ILLUSTRATION.

Case II. The writer may be pardoned for reciting here his own ocular conditions as illustrative of these three subjective methods of determining the amplitude of accommodation. The argument for so doing is that we are reasonably sure of the results of our own personal investigations. With O. D. $+4.12 \subset +.50$ cyl. ax. 90, I am just able to monocularly read the 25 foot line of letters. With a fairly rapid insertion of minus lenses, I am still able to read some of these letters and all of the 30 foot letters through a -0.50 diopter sphere, indicating, by the *concave—at—distance test*, an amplitude of 4.5 D. Binocular tests evidenced from 4.5 to 5.25 D. Provided with my distance correction and carrying out the *concave—at—*

near method, I find that 4 D. is the maximum developable. The *near point* determinations show a monocular near point of 7 inches reading No. 2 Jaeger or about 6 diopters of accommodation.

A case or two illustrative of the value and necessity of various subjective tests, other than the near point tests, as well as objective tests upon the accommodation will be rehearsed in the next chapter.

REFERENCES.

- Landolt.* The Refraction and Accommodation of the Eye. Pages 166-184; 275-289.
- Donders.* The Accommodation and Refraction of the Eye. Pages 28-38; 72-79.
- The American Encyclopedia of Ophthalmology,* Volume I.
- Savage.* Ophthalmic Myology.
- Laurance.* Visual Optics. Pages 56-63; 68; 84; 89; 107; 111; 128.
- Sheard.* Dynamic Skiametry. (Keystone Magazine, 1916 and 1917.)
- Howe.* Muscles of the Eye. Volume I. Pages 144-148.

CHAPTER IV.

A Resume of Methods of Determining the Relative Range and Amplitude of Accommodation and Convergence.

The reader is referred at the very outset of this very brief and meager description of these rather important tests upon the relative range of accommodation and convergence to that most excellent treatise by *Howe* upon "The Muscles of the Eye" (Volume I, pages 309-347). We acknowledge our indebtedness to him for the essentials of the following presentation. Incidentally we must both acknowledge our indebtedness to that great ophthalmologist, *Donders*.

There are upon the market in this country two forms of instruments only, insofar as the writer knows, which may be used for the tests to be discussed in the ensuing paragraphs. These are the devices known as the "optometer" due to *Howe* and the "ophthalmodynamometer" due to *Gardiner*. *Howe* has succeeded in devising by photographic means a near test chart constructed on the basis of the minimum angle of fifty-five seconds which is adapted for testing the vision at each meter-angle from one to twenty. The *Gardiner* instrument is provided with a slide carrying a card printed in several sizes of Gothic type. But both methods suffer from the fact that when "tests are made on persons whose vision is not perfect, or cannot be brought near to the standard of perfection by suitable glasses, a corresponding allowance must be made in the results obtained" (*Howe*).

Donders demonstrated that, for nearly all points within the range of binocular vision, accommodation and convergence are, to a certain extent, independent of each other. There are then two fundamental questions which may be asked as to the relative range of accommodation and convergence.

First. "*Convergence* remaining the same, by how many diopters can accommodation be increased or diminished?"

Second. "*Accommodation* remaining unchanged, by how many meter angles can convergence be increased and diminished?"

THE MEASUREMENT OF RELATIVE ACCOMMODATION FOR CLINICAL PURPOSES.

We have, in these tests, to determine the positive side and the negative side of the relative range of accommodation at any given fixation point. The first of these is determined by concave lenses and the second by convex lenses. We proceed somewhat as follows: The subject looks at the standard test line and the maximum negative and maximum positive lenses, held before both eyes, are ascertained. These values give us, in turn, the powers in diopters of the positive and negative sides of the relative accommodation with visual axes parallel, i. e., convergence nil. Then, using the *Howe* or *Gardiner* apparatus with appropriate test objects, the fixation point is made at 50 centimeters. This demands an accommodation of 2 D. and a convergence of 2 M. A. (about 7° or the equivalent of about 13 prism diopters). By placing negative lenses in the holders, we find the strongest concave lenses with which the line *previously read without glasses*

can be read. The power of these lenses in diopters will indicate the positive side of the relative range of accommodation at 50 centimeters. Without changing the fixation point, the maximum convex lenses under similar conditions of visual acuity as those specified in the above sentence, give the negative range of accommodation. These tests can be continued until the binocular punctum proximum is reached when the patient can no longer read through any negative lenses, showing that the limit of the positive accommodation has been reached. Generally, however, the patient can still read through positive lenses indicating that the negative range of relative accommodation is still operative. If desired, the tests may be continued inside of the binocular punctum proximum until the *absolute* punctum proximum is found at which point the positive lenses necessary to enable the patient to read the type are the only ones with which it can be read. From this data thus obtained most interesting and valuable curves can be plotted using convergence in meter-angles as the X axis or abscissa and the positive and negative dioptric values of the maximum lenses overcome as the Y axis or ordinate. (See *Howe*: Muscles of the Eye, Volume I, pages 324-328; *Donders*: Accommodation and Refraction of the Eye, pages 110-125; *Landolt*: Refraction and Accommodation of the Eye, pages 190-218.)

In *ametropia* the normal relationship between accommodation and convergence does not exist and in consequence the problem becomes more complicated. In myopia we know that convergence is always in excess of accommodation and in hyperopia the reverse

is true. The technique for measuring the relative range of accommodation and convergence in ametropia does not differ from that outlined for emmetropia, but the altered relations between the functions must always be taken into account. A most excellent method, to my mind, is the insertion of the apparent static correction as determined in the light of all distance tests and to then proceed on the basis of semi-normally restored ocular conditions. Particularly is this true of the cylindrical corrections; spherical ametropic errors are easily taken into account.

Clinically or in office practice the above procedure would be too technical and laborious. As a matter of practice, two points suffice, namely 6 meters, or 20 feet and 33 cms., or 13 inches. "Naturally we wish to ascertain if there is any hypermetropia and in so doing we use convex glasses in gradually increasing strength. If no convex lenses are accepted at 20 feet fixation we know there is no negative part of the relative accommodation. If convex lenses are accepted there is hyperopia and the maximum lenses give the measure of the negative part of the relative accommodation. We then place minus glasses before the eyes—about minus 3 D. if he is an emmetrope, or if he is an ametropes varying their strength proportionately. This gives us at once the positive part of the relative accommodation with parallel visual axes or the sum of the two is the total range. * * * It is sufficient to determine at once the amount of relative accommodation with convergence at three meters, namely at about the reading distance. For that purpose the test types which the normal eye can see at one-third of a meter

are given to the patient, and having made sure that the distance at which they are held is about thirty-three centimeters, we place before each eye the strongest concave glass with which the patient can still read that print readily. This gives the positive part of the relative accommodation, understanding that we must subtract in that case three diopters from the strength of the lens, because convergence at one-third of a meter itself necessitates for the normal eye an accommodation of three diopters. In a similar way, by placing convex glasses before the eye while the print is still held at one-third of a meter, and by ascertaining what is the strongest convex glass through which that print is seen, and again making a corresponding correction, we have the negative part of the relative accommodation with convergence at three meter angles." (*Howe*).

Donders stated the important principle that "*the accommodation can be maintained only for a distance at which, in reference to the negative part, the positive part of the relative range of the accommodation is relatively great.*" *Howe* says: "In our studies of the conditions of the muscles we shall find that the most important and apparently the most frequent anomalies are those involving the ciliary muscle. It is desirable to determine whether the action of that muscle is normal, or excessive, or insufficient. At least a general idea as to this power of the ciliary is shown simply by placing a minus 3 D. glass before each eye and asking the patient to read again the distant test type. I have learned to regard this as *one of our most important tests* * * *. If the person cannot overcome

these or weaker minus glasses in proportion to his age or in proportion to his ametropia, then we at once suspect some insufficient power of the ciliary muscles * * *. Ordinarily, if the positive part of the relative accommodation is insufficient with parallel axes and also with convergence at one-third of a meter and if discomfort and headache do exist, then that clue should be followed up."

To illustrate this method let us apply it to a case of actual excessive accommodation commonly called "Spasm of Accommodation." This is a condition quite common in school children and cases of actual excessive accommodation with a low degree of astigmatism are frequent. (1) The range of accommodation is not normal. The near point, as determined by the tape measure and closeness of reading of fine print, is too near the eye. There may be at distance an apparent myopia (say -0.50 D.) and when a low power concave lens is offered the patient may be able to read 20/20. (2) The relative accommodation is altered, for the positive part of the relative accommodation is increased. The negative part of the relative accommodation is abnormally small. With convergence at three or four meters the minus glass which can be overcome is stronger than usual. The causes may include: (a) Excessive effort of accommodation for a considerable time—professional men, bookkeepers and so forth—undoubtedly tends to produce this condition. (b) Glare of strong lights may cause it. (c) General causes, among which may be named primary diseases of the nervous system, reflexes from the stomach or elsewhere and (d) toxemias. In the matter of treat-

ment the so called "blurring" plan is of decided advantage; by this we mean nothing more or less than constant over-correction with convex glasses. Bifocal glasses are often of great assistance; if efforts at accommodation become difficult this may be necessary.

These methods on the measurement of the relative binocular amplitude of accommodation are here called attention to for the reason that they seem to be somewhat of a closed book to the average ocular practitioner. As a matter of fact they are not difficult and the information acquired is often most valuable. It will be noted, however, that this is a *binocular* test, whereas it seems to me more logical to engage in monocular tests, as described in Chapter III, for the two eyes may be distinctly different in their accommodative range and resources. It likewise seems a much more logical procedure to absolutely eliminate convergence from accommodative tests (if the occlusion of one eye does so) and to investigate the accommodation monocularly and to then, under the fusional dissociation tests outlined in Chapter II, investigate the convergence as associated with the accommodation. However, both methods are most valuable and either one practiced consistently will lead to much more scientific work in ministering to the needs of the ocular economy. The analysis should be made, in so far as possible, upon each function separately and then in co-ordination.

These methods have been presented for a further reason and that is this: Dynamic skiametry is, in part at least, an objective method of testing the relation of accommodation to convergence since it is one

method of supplying that lens assistance which will make the relative positive and negative portions of accommodation that which they should be in emmetropia. But we believe that dynamic skiametry is more than this; but if not, it serves as a most valuable test if it quickly and objectively reveals the needed lenticular assistance in the interest of proper accommodative balance at the reading point.

THE MEASUREMENT OF THE RELATIVE CONVERGENCE FOR CLINICAL PURPOSES.

To measure the relative range of convergence similar operations to those described in preceding paragraphs are carried out except that prisms are substituted for spherical lenses. The test chart is placed at various points representing roughly integral meter-angles and prisms are placed before the eyes, base out to measure the positive, and base in to measure the negative, portions of relative convergence. For the average base line (64. mms.) the simplest way to convert degrees into meter angles (approximately) is to divide the number of the prism degrees by 7. The test object is a line, or better a line of coarse type. In the ordinary routine the amount of abduction and adduction are obtained at the far point; this may be considered as the relative range with relaxed accommodation. We then proceed to the relative convergence and divergence at thirteen inches, accommodation being exerted at one-third of a meter. If these tests at the reading point fit in in agreement with those at six meters, ordinarily no further regard need be given them; but in cases of exophoria and esophoria they are most valuable. We have discussed them under fusional convergence in

Chapter III. We note again, in closing this chapter, that normally about two-thirds of the convergence is associated with the accommodation at any point fixed upon. If, therefore, when reading at thirteen inches, accommodation and its associate convergence are normal, about 12° of convergence will be associated with the 3 D. of accommodation and since, assuming an interpupillary distance of 64 mms., some 18° of convergence is required, approximately 6° of fusional or positive convergence is demanded for binocular single vision. If the supplementary fusional convergence at 13 inches turns out to 18° , we may draw two conclusions:—(1) that the abduction at 20 feet is approximately 24° or about the normally accepted standard, and (2) that *Landolt's* criterion is fulfilled, namely, that not more than one-third of the total fusional convergence is called into action at the reading point.

REFERENCES.

Howe—Muscles of the Eye.

Vol. I pages 308-349.

Vol. II, pages 1-90.

Landolt—Refraction and Accommodation of the Eye.

Pages 166-218 and 501-516.

Donders—Accommodation and Refraction of the Eye.

Pages 28-37; 110-126.

Sheard—Physiologic Optics.

(Essay from American Encyclopædia of Ophthalmology. To be reprinted later.)

CHAPTER V.

An Objective Method of Determining the Monocular Amplitude and Range of Accommodation.

All subjective tests should be supplementary to investigations by objective methods. Whenever possible objective methods should be devised and used even though they may fail to agree in *toto* with various subjective tests and even though they may have their probable or apparent inherent source of error. Static retinoscopy is a striking example. Up to the present writing, in so far as the writer is aware, no one has presented an objective method for the examination of the accommodative resources. If such is not the case and the method to be described has been antedated or surpassed, we shall have served with pleasure in emphasizing the simplicity of the method and the value of the data thus obtained to the ocular practitioner. The description of the monocular objective test will be supplemented by its applications to binocular investigations upon the accommodation in the succeeding chapter.

Figures 29, 30 and 31 show diagrammatically the general modus operandi in the monocular method. Each eye should be, in turn, occluded and its accommodative range investigated, since some of the most interesting and important cases from the ocular economic standpoint are those involving marked differences between the accommodative resources of the two eyes.

In practice we so arrange matters that the object viewed (Figure 29) shall be reasonably illuminated.

The flooding of the room with artificial light is not objectionable except from the operator's standpoint. With experience, however, one can use retinoscopic methods and follow the reflexes with ease and accuracy under almost any subdued luminous surroundings.

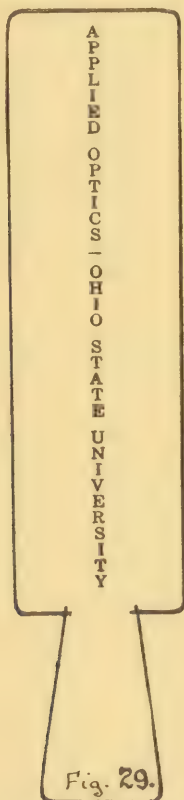


Figure 29. Fixation Test Object for Use in Obtaining the Objective Value of the Monocular or Binocular Accommodative Amplitude.

The patient is given a line of type printed in large letters (12 to 16 point) upon a card about one-half inch wide and fastened to some convenient holder such as illustrated in Figure 29. Or a single line ruled on a card or a pencil will serve satisfactorily as a fixation object, but there is not the incentive to full accommodation as when reading is demanded. The full monocular distance finding, affording as nearly $V=20/20$ as possible, is inserted before the eye to be tested. The patient is then given the test object—which he holds initially at about 13 inches—and told to read the letters. In general we have the patient hold the card slightly to the nasal side during the examination of either eye while we proceed to examine retinoscopically from the temporal side and as close to the visual line as possible.

In Figure 30 we have represented the optical and ocular conditions when the retina and the object viewed are conjugate points and the exact or requisite number of diopters of accommodation demanded for the point fixed are supplied. Under these conditions, therefore, with the accommodative point kept constant at F and the mirror A in the same plane a neutral shadow condition should obtain and by moving the retinoscope to C —an inch nearer the eye—a hyperopic condition would be revealed or by withdrawing an inch further from the eye, as at B , a myopic condition would be evidenced. By then moving or having the patient move the test-object nearer the eye the actual near point will be found as soon as the retinoscopic mirror has to be operated in a plane back of the fixation point in order to obtain a neutral shadow.

These are ideal conditions in that we are assuming the presence of a true or artificially produced emmetropia and a perfectly innervated and functioning ciliary and lenticular action.

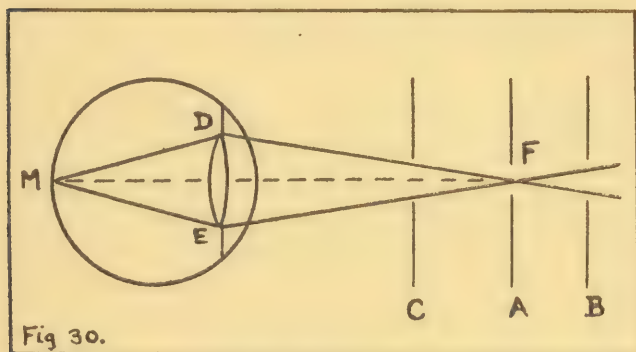


Figure 30. Illustrating the Optical Principles Involved in the Objective Monocular Test upon Accommodative Amplitude.

In general we find that when the patient, wearing the full distance correction, reads monocularly the letters (which, by the bye, may be as small as the patient can see), there is a "with" or hyperopic motion indicating that the point conjugate to the retina in an eye optically statically perfect is not at the position of the object viewed but at a position somewhat in front of that point, i. e. further from the eye. Three valuable tests may be made. *First*, with monocular fixation and observation retinoscopically at any point desired the operator can find that convex lens power which must be added in order that the monocular accommodative demands, in the interest of conjugacy of

retina and object viewed, may be met. This would be shown by the additional lens power needed to give a neutral retinoscopic reflex. Suppose that 1 D. is thus demanded when both fixation and observation points are at thirteen inches: our interpretation would be that objectively an assistance to the accommodation, over and above the assistance (or burden in cases of over-corrected myopia) afforded by the static finding given the eye, is required to relieve the accommodation of an extra burden. Notice that we specify *minimum* amount of additional lens power to produce neutralization skiascopically; more assistance might be and generally would be accepted under the method of procedure we have disclosed. *Second*, observation may be kept constant at any distance specified and the test-object drawn closer to the eye until a neutral shadow is obtained. In Figure 31, let F be the point viewed and A the position of the operator's mirror. If a certain test shows that DF is 10 inches (4 D.) and DA is 13 inches (3 D.) we should conclude that the accommodation actually available at ten inches is sufficient only for optical conjugacy at 13 inches, hence indicating the need of a diopter of lenticular assistance. *Third*, by approaching the object closed and closer to the eye a point will finally be found such that no nearer approach to the eye changes the neutral condition of reflex as retinoscopically observed at the closest point to the eye. In testing, therefore, for the near point objectively we proceed as follows: The patient draws the test object as near the eye as will still permit of its reading. To the observer at thirteen inches the retinoscopic reflex will show an "against" or myopic condi-

tion indicating that he is outside of the optical ocular far point dynamically considered. The practitioner then moves forward until he obtains the neutral shadow position. The test-object is then to be carried still closer to the eye (blurred image makes no differ-

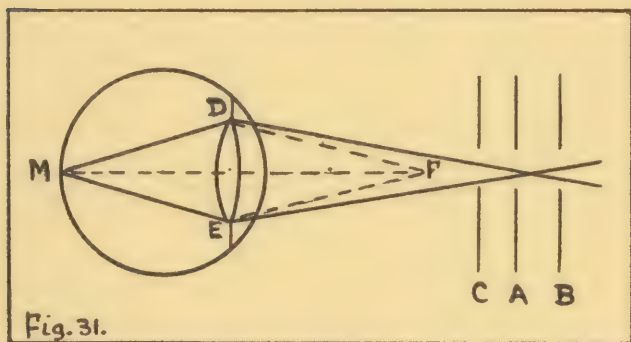


Figure 31. Illustrating the Optical Principles Involved in the Objective Monocular Test upon Accommodative Amplitude.

ence) and the nearest point of neutral shadow found and measured. This gives the *apparent* near point under whatever ocular conditions the test is made (ordinarily when wearing the distance correction) and from it the range and amplitude of accommodation are easily determined. We measure the distance $D A$ (Figure 31) and not $F D$. We occasionally vary this test, and with observation and fixation at thirteen inches, produce neutralization of shadow and then proceed as outlined above. We are, however, partial to the test in which the static finding is worn.

The method is certainly very simple and quickly carried out. The question is, are there any inherent

errors? Yes; those of observation and optical imperfections, lack of response on the part of the person under test, and the difficulties of making accurate measurements of distances. For this latter purpose we use a light-weight, narrow tape-measure, one end fastened to the trial frame with due allowance for distance from the cornea, and the other end weighted, the tape when in use being carried between the finger and thumb of the hand holding the retinoscope.

These tests must certainly suggest themselves to the reader as being most valuable, especially in finding the range and amplitude of accommodation in children (one can employ small colored pictures pasted on the rear side of the test-object shown in Figure 29), in presbyopia, in subnormal accommodation, in excessive accommodation, in amblyopia when we are uncertain of whether or not accommodation is still active because of the uncertainty of subjective tests by virtue of the reduced visual acuity.

Likewise, we are provided with an objective method which tells us whether or not accommodation is proportionately enforced in those rather frequent cases, mentioned in Chapter III, in which the patient, usually young in years, is not able to read fine print at fourteen inches but can read it when brought up very close to the eye. Our answer is that these tests demonstrate the universality of lack of proportionate accommodative action and that such type is read at points abnormally close to the eye because of increased sizes of retinal images, constriction of pupil and narrowing of palpebral fissure.

Furthermore, these objective tests show that the

amplitudes of accommodation are in closer agreement with the results tabulated in Chapter III under the concave-at-near method than they are with monocular near point and binocular concave-at-distance methods.

SOME ILLUSTRATIVE CASES.

We close the chapter with a few illustrative cases.

Case 12. Normal Monocular Accommodative Range. Miss E. N. Aet. 25 years. Static Skiametry, O. U. +1.00 D. S., Dynamic Skiametry, O. U. +1.50 D. S., Subjective, O. U. +1.25 D. S., Objective monocular accommodation, each eye, 6 inches or 7 D.; binocular objective accommodation 5 inches or 8 D. Monocular near point, reading No. 2 Jaeger through distance correction, showed punctum proximum at 4.5 inches. All accommodative convergence tests showed 3° esophoria at near, 1° esophoria at distance, wearing subjective findings. Concave-at-near test at thirteen inches demonstrated that each eye was possessed of 8 D. accommodation.

Case 13. Unequal Binocular Amplitude of Accommodation. Mr. E. P. B., Aet. 21 years; headaches; dryness of eyes; cannot read for any length of time; sensitive to light. Distance correction, acuity equally good, O. D. +.50 D. S. —0.37 ax. 180, O. S. +.87 D. S. —0.37 ax. 180. Monocular objective accommodation with distance correction, O. D. 5 inches or 8 D. and O. S. 4 inches or 10 D. Binocular objective accommodation point at 4 inches. Concave-at-near methods demonstrated O. D. 8 D., O. S. 10 D. With distance correction before the eyes the following facts were disclosed; binocular tonicity test 9° exophoria; ductions, O. D. abduction 8°, adduction 14°, O. S. abduction 7°.

112 OBJECTIVE MONOCULAR ACCOMMODATIVE TEST.

adduction 13° . Accommodative-convergence tests at 13 inches, with fusional convergence passive, showed by one test 4° base in or 2° exophoria (assuming a physiologic exophoria of 6°) and by another test 2° base in or 4° exophoria. The reserve convergence was found to be 23° or more. The binocular near point subjectively determined was 3.5 inches. The concave-at-near monocular tests on accommodation showed O. D. 8 D. and O. S. 10 D. These tests then demonstrate: (1) that the convergence as associated with the accommodation is overly taxed, probably in the interest of relieving the fusional convergence. (2) that the reserve convergence is amply able, except under periods of strain at near work, to overcome the tonic divergence but that the burden upon it is excessive, (3) that the amplitude of accommodation of the right eye is greater than of the left. We prescribed O. D. $+.37$ cyl. ax. 90, 1° base in and O. S. $-.37$ cyl. ax. 180, 1° base in, chiefly for distant use.

Case 14. Amblyopia. In a particular case of a man, aged 30, the static retinoscopic findings were O. D. $+3.00$ D. S., O. S. $+5.00$ D. S. Dynamic skiametry showed O. D. $+3.50$ D. S., O. S. $+6.50$ D. S. Static subjective tests gave O. D. $+2.50$, V=20/20 and O. S. $+4.00$, V less than 1/10 which could not be improved upon. The monocular objective accommodative test showed that the right eye had 4 D. of accommodation but that the near point accommodatively for the left eye was 15 inches or 2.5 D. Some 8° of esophoria was elicited at distance. We are satisfied that little can be done for the left eye for it has very low visual

acuity and practically little amplitude of accommodation.

Case 15. Anisometropia with Good Range of Accommodation. Young girl, aged 10 years. Static retinoscopic test showed O. D. +3.00 D. S. $\ominus$ -5.00 ax. 10; O. S. +0.37 $\ominus$ +.50 ax. 90. Subjectively, O. D. -2.25 $\ominus$ +4.75 ax. 100 gave $V=8/10$ while the static finding for the left eye gave $V=10/10$. The monocular objective accommodation, wearing the above correction, showed O. D., 5 D. and O. S., 8 D. Distance muscle tests evidenced 4° exophoria and tests at 13 inches demonstrated 10° base in and 12° in, or approximately 6° of exophoria. The maximum reserve convergence at 13 inches was 16°. We gave the subjective finding for constant wear with advice to use the pencil method (a drawing of the finger or a pencil toward the eye until diplopia ensues) for developing additional convergence reserve and to cover the left eye for short periods of time several times a day and to exercise the right eye by reading coarse print. This has been done with the result that after six months her accommodation in the right eye has developed an additional diopter and her reserve convergence some 5° more strength.

Case 16. Presbyopia. The subjective findings, in good agreement with the static retinoscopic results, gave in the case of a woman 58 years of age normal acuity under O. D. +1.75 D. S. $\ominus$ -1.25 ax. 30 and O. S. +2.00 D. S. $\ominus$ -1.00 ax. 165. Dynamic ski-
ametric tests at 16 inches (where she desired to read) gave O. U. +4.00 D. S. $\ominus$ -1.25 ax. 180. The objective accommodative test, the patient wearing the

distance correction, demonstrated a monocular near point of 20 inches or 2 D. while the binocular test showed 17 inches or 2.37 D. Therefore, for reading purposes at 16 inches (equals 2.5 D.) and allowing her to retain one-half her available amplitude of accommodation in reserve, we gave her an additional +1.75 D. S. binocularly. The interesting part of this case is the following: 1° exophoria at distance; at the reading point some 20° base in or 16° exophoria under the accommodative-convergence test wearing the reading correction; a reserve convergence of about 12°. We gave this patient 1.5° prisms, base in, incorporated in her reading glasses and did nothing further since she has been for years and is now under medical treatment "for her nerves." We hope we will not be misunderstood when we say that the woman is enjoying her life as she has not for years, for she came wearing a correction which she had worn for six years involving cylinders which I am positive never had their corresponding neutralizers in her eyes.

CHAPTER VI.

An Objective Method of Determining The Binocular Range and Amplitude of Accommodation and the Effects Which Lateral Muscular Imbalances Have Upon the Same.

This chapter presents the monocular objective method of determining the range and amplitude of accommodation as made applicable to binocular investigations upon the functions of accommodation in each eye as correlated with that of convergence. The one very vital factor which enters into these binocular tests and which is, presumably, absent from monocular investigations when the eye not under examination is occluded, is that of *convergence*. For this term *convergence* we ought properly to write *binocular single vision*. As a result there is ostensibly less likelihood of a true analysis of ocular conditions being made and less likelihood of an ability to interpret the data obtained when two functions, not wholly independent neither wholly dependent one upon the other, are investigated under conditions in which they are co-ordinated in some manner such as will give binocular single vision (convergence) and distinctness of vision (accommodation), than there is when each function is investigated, insofar as possible, by itself. The methods and tests have been presented in the foregoing chapters.

But the binocular methods to be described are most valuable in many cases and as a well-known American ophthalmologist and an authority on ocular muscles said to me: "We are still guessing these optical puzzles"; hence that which is of value even in a small

percentage of cases is worth preservation and use. Marked departures in the values of the objectively obtained binocular and monocular near-points are nearly always indicative of disturbances in the extrinsic muscles or their innervations or the supplementary convergence. Excessively close binocular near-points as compared with the monocular tests usually accompany conditions of over-convergence or relatively excessive accommodation, while in those circumstances in which the binocular accommodative near-point is farther from the eyes than is the monocular objectively determined punctum proximum, weakness of convergence or abnormal divergence is present.

In determining the binocular range of accommodation we employ a test object such as that shown in Figure 29. The subject approaches this toward his eyes while the practitioner follows behind with his retinoscope until he has determined the closest position at which he can obtain a neutral shadow even though the test object may be approached still nearer the eye. We have diagrammed in Figure 32 the ideal conditions of convergence and accommodation and the determination of the binocular near point and have shown in Figure 33 the ordinarily found arrangement of fixation and position of the observer when the closest neutral shadow position is obtained. For if, as in Figure 32, we have a pair of eyes in which the monocular accommodations are so perfectly regulated that one diopter of innervation produces one diopter of actual accommodative or refractive change and if the accommodation as associated with convergence is so perfectly adjusted that, in conjunction with the supple-

mentary or fusional convergence, the commonly accepted standard relation of three to one (this ratio being dependent upon the value of the meter-angle) between convergence and accommodation obtains so

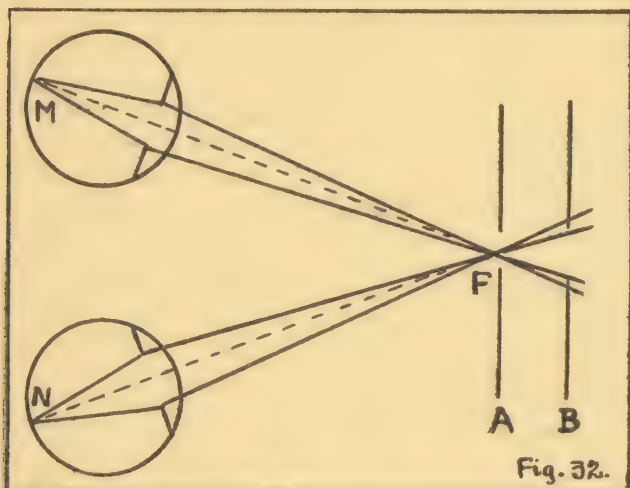


Figure 32. Illustrating the Optical Principles and Procedure in the Binocular Accommodative Amplitude Tests.

that the convergence and accommodative fixation points are one and the same, then the fixation point *F* and the observation point *A* will remain one and the same until the binocular near point is reached. A further approach to the eyes will, however, give a "with" motion (when the plane mirror is used) since the accommodation can no longer keep up with the convergence, i. e. an object would be seen single but indistinctly or double but distinctly, and the binocular *dynamic* far-point (or subjective near-point) would be back of the fixation point.

118 OBJECTIVE BINOCULAR ACCOMMODATIVE TEST.

In the majority of cases we find the conditions as shown in Figure 33 in which the fixation point *B* is nearer the eye than the neutralization of the retinoscopic shadow position at *O* when the same has been determined at its closest position to the eyes. That the binocular near point is ordinarily, either by subjective or objective methods, nearer the eyes than is the monocular near point argues for a greater activity on the part of accommodation when associated with convergence than when not so associated and especially under the impetus of overconvergence when the

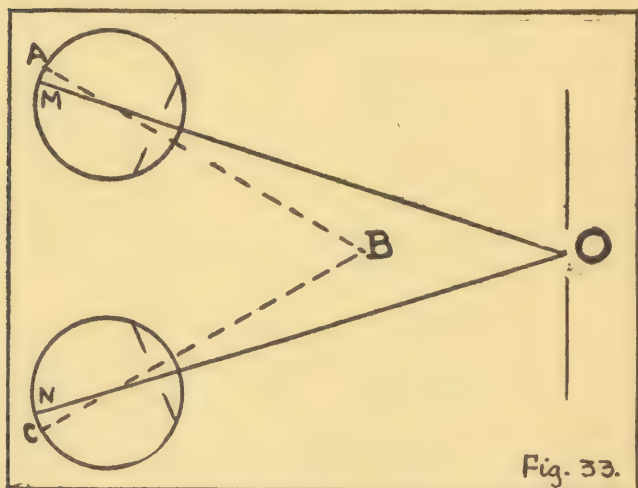


Figure 33. Illustrating the Optical Principles and Procedure in the Binocular Accommodative Amplitude Tests.

convergence punctum proximum and binocular accommodative near point approximate each other. This is,

however, one of the intricate ocular problems and, insofar as we are aware, it is rather commonly accepted that "whatever may be true of other associated brain-centers, it appears that the center of the ciliary muscles and the third conjugate innervation center (the one to converge both eyes) can have the associated impulse to run in only one direction; that is, from the former to the latter." (*Savage*). Such a statement is probably correct when we have reference to the convergence as associated with the accommodation but it does not necessarily follow that the third member which enters into binocular single vision, namely the fusion convergence, may not alter the convergence associated with certain accommodative conditions and thereby make available greater accommodative possibilities. In fact, the proof is conclusive that the fusion convergence serves as the correlating medium between accommodation and convergence in order that fixation may be one and the same accommodatively and convergently when possible.

We may well ask with *Howe*: "Of what clinical importance is the difference between the binocular and monocular near point?" To my mind the answer lies in the *process of convergence* or as the result of the act of convergence. For if the eye is tested as to its accommodative resources in its straight-away, parallel-axis position (as when looking at twenty feet) no convergence is involved, hence we should expect to experimentally obtain the minimum value of the accommodative resources when this function is investigated at 20 feet. When the tests are made monocularly, either by objective or subjective methods, only that

120 OBJECTIVE BINOCULAR ACCOMMODATIVE TEST.

convergence which is associated with the act of accommodation is in operation. This accommodative convergence we believe to be, under standard conditions, less than the amount demanded for binocular single vision at any given near point. Hence this must be supplemented by fusion convergence. We likewise have reason to believe that the portion of the convergence demands met by the accommodation increases as the fixation point is approached toward the eyes, since the fusion convergence increases at points closer to the types as shown by such investigations as those recorded by *Maddox* and given in Chapter II. The accommodative and convergence functions are in part independent of each other and in part interdependent; we should, therefore, expect the monocular accommodative tests to indicate greater values of the accommodation when associated with accommodative convergence than when tested at points involving no such convergence and less, in turn, than the results shown by tests upon the binocular accommodative resources. There must, therefore, be an interplay of accommodative and fusional convergence, not necessarily through physiological or anatomical channels, however, whereby the convergence makes possible a slightly greater dynamic refractive change under a given delivery of innervation to the accommodative mechanism. Under excessive positive convergence tendencies or in which the positive fusion convergence is extraordinarily large we should expect a greater binocular than monocular range of accommodation. A binocular amplitude of accommodation which is in excess of the monocular amplitude by a diopter or

more is, in general, indicative of an associated positive overconvergence or a subnormal accommodation. When the reverse conditions exist, and the binocular accommodative near point is farther from the eyes than is the monocular, we may conclude that there is a deficiency in either the accommodative convergence or the positive fusion convergence or both.

In the clinical use of the binocular test we supply the eyes with the full distance binocular findings (the same, however, as used in the monocular method) and determine the nearest point at which the shadow stays neutral. For, if we are outside of the accommodative far-point, the shadow or reflex will move "against" the mirror motion (using the plane mirror) and if inside, it will move "with." There is evidently one position of the observer's mirror in which, with a constant approach of the test object to the eyes, it will be at the closest point possible for a neutral shadow.

It may be claimed that this method is similar to, or the same as, that known by the name of "dynamic skiametry." It is, in part, a modification of this system and when the dynamic skiametric tests, with fixation and observation at the customary reading distances, are being carried out, these monocular and binocular range of accommodation tests can be readily made. But the nature and purpose of these tests are entirely different from those involved in dynamic skiametry. In the former we are testing for the maximum available amplitude of accommodation, while in the latter it is presumed that there will be objectively indicated that lenticular assistance at any given fixation point such that accommodation and convergence will be harmoniously correlated at the point of test.

We close the chapter by a citation of two cases illustrative of the points we have been discussing.

ILLUSTRATIVE CASES.

Case 17. The Binocular Amplitude of Accommodation as Objectively Determined Greater than the Monocular Amplitude. Miss E. K. Aet. 12 years. Complains of frontal headaches and inability to read in the late afternoons or evenings. *Static retinoscopic* tests evidenced O. U. + 1.25 D. S. *Dynamic skiametry*, the patient wearing the distance correction, fixation and observation being made at 13 inches, disclosed a decided "with" motion requiring O. U. + 3.00 D. S. in toto to neutralize. Binocularly, under *subjective tests*, O. U. + 1.00 D. S. was accepted giving $V=8/10$ to $10/10$. The *accommodative convergence* tests showed 7° esophoria, the *tonicity* tests at 20 feet evidencing 4° esophoria, the patient wearing the distance findings. The *objective monocular accommodative amplitude* test showed 3.5 D.; the *binocular* test 5 D. The *subjective accommodative* tests disclosed the fact that the patient could not *monocularly* read No. 2 Jaeger at 13 inches and that the same was readable *binocularly* with great difficulty.

With a reading correction of O. U. + 2.00 D. S. No. 2 Jaeger could be read but not closer than 10 inches. From the nature of the case and the child's nervous condition we prescribed O. U. + 1.25 D. S. for constant wear and forbade the use of the eyes for reading or any other close work.

Case 18. The Binocular Amplitude of Accommodation as Objectively Determined Less Than The Monocular Amplitude. Mr. J. W. Aged 25 years. Suffered

a nervous breakdown two years ago and is still under his physician's care. His eyes have troubled him a great deal; has worn glasses for years. *Static retinoscopy* showed O. D. $+0.62$ D. S. $\subset +1.12$ ax. 90, O. S. $+0.62$ D. S. $\subset +1.50$ ax. 90. *Dynamic skiametry* disclosed practically the same findings; if anything a trifle *less spherical power*. *Subjectively* it was found that the static retinoscopic findings afforded satisfactory vision. The *monocular objective accommodative* test, wearing the distance corrections, showed near points of 8 inches, equivalent to 5 D.; the *binocular* test disclosed a near point of 12 inches or 3.3 D. of accommodation as the maximum that could be used (not developed, however) in binocular single vision. The reason why these conditions existed is evident from the following statements: (1) a *tonic exophoria* of 4° , (2) an *accommodative convergence* deficiency of 14° , requiring 20° base in at the reading distance to bring the test objects in alignment and (3) a *positive fusional convergence reserve* of 8° . We may say, in conclusion, that we ordered two pairs of glasses for this young man, one for distance wear and with no prisms incorporated and another pair for reading including in the prescription therefor 2° base in O. U.

CHAPTER VII.

The Principles and Methods of Dynamic Skiametry.

A rather brief presentation of some of the essential principles and methods of a system known as 'Dynamic Skiametry' must suffice in the closing paragraphs of this rubric on various dynamic tests. The reader who is specially interested in this system of ocular refraction will find considerable that is of value with reference to the same in the book entitled "Dynamic Skiametry in Theory and Practice," by *A. J. Cross*, and in the writings upon this subject by the author of this compendium.

The procedure as commonly adopted in this method is to initially obtain by static retinoscopy those refractive findings which put the eyes, monocularly, in an optical condition such that the retina and the distant point, *presumably* passively fixed, are conjugate points. The distance corrections are then inserted before the eyes under test and the patient is told to read aloud a series of letters indiscriminately arranged or count a number of fairly large dots upon a test card attached to the retinoscope. The test is a binocular one, for both eyes are involved, hence convergence and accommodation are both demanded in order that binocular single vision may ensue. While the patient is reading the letters or counting the dots the examiner takes note of the character of the reflex or shadow in each eye, one after the other. Should he find a "with" motion, using a plane mirror or the *Cross* form of dynamic skiascope, the practitioner then proceeds, according to the method generally advocated, to add such convex

lenses as will give a slight over-correction binocularly as evidenced by the "against" character of the retinoscopically obtained shadows. We believe that this statement covers, in essentials, the mechanical procedure, unless we add to these remarks the further statement that, should an "against" motion be obtained with fixation and observation at any given point, concave lenses are added until a neutral shadow is found in both eyes. The fixation point, when fixation and skiascopic observation are made at one and the same position, may be varied to suit the practitioner. Commonly chosen points vary from ten to twenty inches from the eyes. This method, which we may describe as the simultaneous-fixation-observation procedure, may be modified, as has been suggested by *Cross*, and fixation may be demanded at any desired point through the medium of a suitable chart or test object, while the reversal of skiascopic shadows is sought at another point. For example, fixation may be made at 40 inches and the reversal sought and found at 26 inches. This procedure is analogous to that which may be used in myopic cases under static retinoscopic methods in which the points or positions of retinoscopic reversal may be located. For our own part we rarely use either of these static or dynamic 'determination of reversal point' methods, for the reason that measurements of distances are likely to be too inaccurate to be of value from an exact refractive standpoint. This 'measurement' method of finding the skiascopic neutralizing lens quantity is, however, very rapid and satisfactory for obtaining the order and magnitude of the error, in either static or dynamic procedures, particularly in cases where the reversal point is within a one-meter

distance. The 'fixation-at-one-point and observation-at-another-point' method of operation in dynamic skiametry has been criticized by many on the basis that it is impossible for the patient to read the letters on a chart and still have an observational reversal point at another position. This criticism is unwarranted provided there is not instituted a change of lenses before the patient's eyes to bring the skiascopic reversal at any specified point. For 'ray values' have their equivalent lenticular counterparts. If fixation should be made at 20 inches, for example, and the operator should find a neutral point at one meter (equivalent to 1 D.), then, under the procedure as we shall outline it, we have evidence that +1 D. lenses are required in order that the positive range of relative accommodation, the negative range of relative accommodation, and convergence, may be properly correlated. But, more of this in the succeeding paragraphs!

Cross recommends the use of his own peculiar form of skiascope which carries a light frame attached to the mirror support in such a manner that one fixation card is slightly behind and the other slightly in front of the operator's nodal point. The fundamental notion underlying this device is that when full correction has been approximated with fixation at the card more remote from the subject's eye, a quick change to the slightly nearer fixation object is made possible and that, if there is then a *reversal* of shadow, a correct refractive finding as to the needs of a pair of eyes *at the point fixed*, in order that the accommodative and convergence relations may be properly correlated, has been found. The writer differs from *Cross* as to his notions of just what this dynamic test means and,

therefore, in his *modus operandi*, and uses the simple form of plane retinoscope with a small card attached thereto and printed in heavy-face six point type. In passing, let it be stated that the card which serves as the test object should be sufficiently illuminated; we carry out such tests in a room well-lighted artificially.

In his presentation of the theory of dynamic skiametry *Cross* writes: "While the static method of practicing skiametry is one where the ciliary muscle of an eye is at rest, the dynamic method is the exact reverse of this, and is made while the accommodation is exerting itself sufficiently to readily accept refractive assistance up to a point where its relation with convergence is interfered with * * *. So in *dynamic* skiametry a call is made for a pronounced increase of the accommodation by having the patient read a series of test letters placed on the observer's brow," (the writer then gives other methods), "then varying this tension as judgment teaches, and by being able to easily supply required artificial lens power, *the accommodation is reduced to its normal relationship with convergence*. And most eyes, no matter what the age of the patient may be, *will only surrender the accommodative excess* which has been required to maintain near-vision * * *. The relationship between accommodation and convergence, if roughly stated, is found to be in about the proportion of one to three for the two eyes." The writer's interpretation of *Cross's* statements are that he (*Cross*) believes that the accommodative excess will be surrendered only to the extent of the establishment of a normal "one to three" ratio between accommodation and convergence.

We are not entirely in accord with the theory of

Cross as quoted or as amplified in his book. We are, however, in agreement with the statement that *tests can be made* to determine when the accommodation is reduced to its normal relationship with the conditions of convergence as demanded at any fixation point. But our procedure and interpretation are somewhat different. In Chapter IV we have given a summary of methods of obtaining the relative range of accommodation (i. e., by how many diopters it can be increased or decreased) when convergence is constant. When, therefore, fixation is made at any point a definite convergence is involved. By the *Gardiner* or *Howe* apparatus we should then proceed to find out how much convex lens can be added until the test type can no longer be read. This gives the negative range of relative accommodation. Is not, then, dynamic skiometry, when practiced with fixation and observation points identical, and convex lens power added until *reversal* occurs, simply and purely an *objective method of determining the negative range of accommodation*? We believe it is, and if so it is a most valuable asset in investigations upon ocular conditions. A citation from *Cross* (which can be repeated by anyone in almost any case of hyperopia) supports this view. He writes: Case I. Fixation, 40 inches; observation 39 inches. Shadow *with* the mirror. Can add plus 1 D. before reversal occurs. But with fixation and observation at sixteen inches, a total of plus 1.50 D. can be added before reversal takes place. Same result is obtained with fixation and observation at thirteen inches." These results are in accord with an affirmative answer to our question, for relative accommodation-convergence curves show, except in exceptional

cases, a decrease in the positive range (through concave lenses) and an increase (through convex lenses) of the relative amplitudes as the fixation and hence convergence are changed. The writer believes that a careful study of a few cases by both relative range of accommodation and convergence subjective methods and by dynamic skiametric tests as explained above will substantiate this explanation.

The question may, therefore, be very properly raised at this juncture: Is there any objective method of procedure whereby one can determine the lenticular assistance needed in binocular single vision at any given reading point such that the proper relations between positive and negative ranges of relative accommodation and the convergence may be met so as to establish normal or balanced conditions? We again answer in the affirmative and say that there should be placed before the eyes, for any given fixation and observation distances, the maximum convex or minimum concave lenses which will just give a *neutral* shadow and that we should not proceed to the point of adding such less quantities as will produce reversal. The distance binocular findings may be inserted previous to this test and they may be made the basis of further lenticular changes under this proposed system of dynamic skiametry until *neutrality* of *shadow* arises. To illustrate: We found in a certain case just previous to our writing these sentences the following:—static retinoscopy, O. U. +1.00 D. S.; dynamic skiametry, as advocated above, at 13 inches, +2.00 D. S., and for *reversal* +3.00 D. S. The positive range of relative accommodation at 13 inches was found to be 3 diopters and the negative range 3 D.

Such data shows that the positive part of the relative accommodation in this case was abnormally taxed by the hyperopia and that by its alleviation to the extent of 2 D. a balanced condition between accommodation and convergence was established. As *Donders* stated, "The accommodation can be maintained only for a distance at which, in reference to the negative part, the positive part of the relative range of the accommodation is relatively large." The foregoing data shows that such was not the case. We believe, therefore, that dynamic skiametry, when properly practiced, will afford a quick and accurate method, in general, of finding that lenticular assistance needed at the reading point to re-establish normal relations between the positive range of accommodation, the negative range of accommodation and the convergence.

The most animated discussions have arisen as to whether or not the dynamic skiametric findings can be worn for distant use. In other terms, the claim is made by some that the dynamic findings indicate the lenticular assistance *really* (or ultimately) demanded by a pair of eyes, and that this method operates (from the accommodative strain rather than the total relaxation of strain method of attack) to the same purpose as does a cycloplegic—namely, the determination of the full refractive demands. Hence the two methods, although radically different in method and in action, look toward the same sort of an indicated answer. The static finding without cycloplegics or without fogging, and the dynamic findings at near-points constitute the two *extreme* sets of findings between which the final prescription given is to be determined upon by reason of other dynamic ocular

tests at distant and near points in particular. Other investigators claim that the findings as made by dynamic skiametry are those suitable for proper correlation of accommodation and convergence at the point fixed. They claim that the method affords a reading correction only. From a strictly scientific basis the writer believes that the latter view is, in general, the only one which can be substantiated. Hence, if a practitioner prescribes under all conditions that which leaves the visual acuity at or nearly normal, then no dynamic methods will be of any service to him. The static findings taken in conjunction with the dynamic objective and subjective tests will lead to the accumulation of that data from which the practitioner, in the light of his training, his experience and his *scientific study*, can formulate those lens prescriptions which will serve the real demands of the ocular regime and not simply cater to $V=20/20$ acuity tests. The question, "Would you prescribe from dynamic skiametric findings?" we would emphatically answer in the negative and say that we would prescribe from the results of no particular method but from the analyzed results of all the methods and data obtained. And, in passing, let it be said that a scientific study of a pair of eyes cannot be made in fifteen or twenty minutes.

The dynamic skiametric test is easily made by anyone familiar with the practices of retinoscopy. If you have never tried this system, take the findings at the fifteen inch fixation and observation points in the manner we have outlined and make an intensive study of fifteen or twenty cases by all tests possible. This will be of more value to the reader than many, many pages of written description.

ILLUSTRATIVE CASES.

We have cited the dynamic skiametric findings in the rehearsal of a number of illustrative cases in the foregoing pages. It appears, therefore, unnecessary to supplement this closing chapter with many practical examples, but we may be pardoned the addition of a few characteristic cases and a few rather exceptional ocular conditions in which dynamic skiametry has been a valuable aid in the solutions to which we have finally arrived.

Case 19. Simulated Myopia. Young lady, aged 23 years. Complained of frontal headaches, eye burn, photophobia and the usual train of accommodative strain symptoms. *Static retinoscopic* tests showed O. U. -0.62 D. S. *Dynamic* skiametry, with observation and fixation at 15 inches, gave O. U. $+0.50$ D. S. for neutralization and $+1.50$ D. S. for reversal of shadow. *Subjective binocular* tests showed that O. U. -0.25 D. S. gave normal acuity and that O. U. $+0.50$ D. S. reduced it to not better than $7/10$. The *tonicity* tests gave 2° esophoria and the *accommodative convergence* test evidenced 7° esophoria. These latter investigations were made without any lenses before the patient's eyes. We gave O. U. $+0.50$ D. S. which relieved the symptoms and after a few weeks' time gave practically normal acuity as well as comfort.

Case 20. Hyperopia with High Esophoria. A young man, a chemist, who had suffered great ocular discomfort for years, presented himself and gave an interesting history of all kinds of ocular treatment. The observations on this case have covered a couple of years and cannot all be given here. The initial examination (as well as the last one for that

matter) evidenced through *static retinoscopy* O. U. +1.00 D. S. $\ominus$ +0.50 cyl. ax. 90. *Dynamic skiametry* showed that +2.50 D. S. $\ominus$ +0.50 cyl. ax. 90 gave neutral shadows at 13 inches. Without correction of any character, the *tonicity* tests showed 10° esophoria and the *accommodative convergence* measurement some 13° esophoria. *Subjectively*, O. U. +1.25 D. S. $\ominus$ +0.50 cyl. ax. 90 in the first examination did not give better than 8/10. We gave this young man O. U. +1.37 D. S. $\ominus$ +0.50 cyl. ax. 90 for constant wear. He became accustomed in a little time to the "blurring" caused by these. We prescribed for him a year and a half later the full *dynamic skiametric* findings. These he wears with comfort and efficiency in his work but with an acuity not quite equal to 8/10. The criterion of normal visual acuity is a poor one in many cases, especially in those conditions similar to the one we have just described.

Case 21. Peculiar Condition of Monocular Astigmatic Requirements at Reading and Distant Points. In a particular case seen recently *static retinoscopy* indicated O. D. -1.25 D. S. $\ominus$ +4.50 cyl. ax. 100 and O. S. -0.75 D. S. $\ominus$ +3.50 cyl. ax. 80. With slight modification these gave normal acuity conditions under the minimum possible binocular concave lenses. *Tonicity* tests gave 4° exophoria and *accommodative convergence* investigations showed 8° exophoria. The *fusion convergence* reserve at thirteen inches indicated 22°. The *monocular objective accommodative* method gave O. D. 5 D. and O. S. 6 D., while the binocular test indicated about the same. *Dynamic skiametry* gave, under a neutral shadow method, O. D. -0.75 D. S. $\ominus$ +6.50 cyl. ax. 100 and O. S. -0.25 D. S. $\ominus$ +4.00

cyl. ax. 80. The marked difference between the *dynamic* and *static* values for the right eye is worthy of comment. Under occlusion, it was found that the patient could not read with her right eye No. 3 Jaeger type ($V=0.75$ D.) through the distance correction but that, with the *dynamically determined cylindrical correction*, she could read No. 1 Jaeger as close as 10 inches. Other corroborative tests of a nature similar to those outlined in this brochure were carried out and the patient was given the following prescriptions: For distance, O. D. -1.00 D. S. $\ominus +4.50$ cyl. ax. 100, O. S. -0.62 D. S. $\ominus +3.62$ cyl. ax. 80; for reading, O. D. -0.87 D. S. $\ominus +6.00$ cyl. ax. 100 and O. S. -0.50 D. S. $\ominus +4.00$ cyl. ax. 80. The old glasses, given her after an examination under a mydriatic, were O. D. -1.00 D. S. $\ominus +4.50$ cyl. ax. 100 and O. S. -0.75 D. S. $\ominus +4.50$ ax. 80. With the reading glasses as prescribed she has done near work in comfort by the hour—a procedure impossible before.

Case 22. A Case of Divergent Strabismus Coupled With Autonomic Control of the Refractive Status of the Eyes. An article dealing with a most interesting case in which all monocular static methods gave a hyperopic correction, but in which dynamic skiametric methods and all dynamic tests indicated the advisability of the use of concave lenses, was reported by the writer in the *Ophthalmic Record*, August, 1916 and reprinted in *The Keystone Magazine* and *The Optical Journal* during September, 1916. Space forbids our giving this case in detail; the reader is referred to these journals for this as well as other valuable papers along the line of refraction. We quote from this article the following paragraph:

“The data thus elicited clearly evidenced the following facts: (1) the refractive error of each eye, axially considered and dissociated from its mate, was hyperopic; the eyes when in this condition or when corrected for this defect were decidedly negatively convergent, (2) when the fusion faculty was exercised and sufficient innervation supplied through the proper centers to give the proper or necessary positive convergence and thus correlate the eyes from this standpoint, the ciliary through the third nerve innervation also responded and caused a lenticular change such as to produce a myopically refractive condition. The logical line of reasoning seemed, therefore, to be somewhat as follows:—the wearing of minus lenses by this hyperope would force the supply of necessary innervation to accommodatively overcome the correction given and thus supply the necessary innervation to produce positive convergence.”

CONCLUSIONS RELATIVE TO DYNAMIC SKIAMETRY.

Elsewhere (The Keystone Magazine, January, 1917) the writer has given a summary of some of the main conclusions relative to dynamic skiametry and its service in ocular refraction. We quote these at length.

(1) Data of value accrues to the practitioner through investigations by dynamic skiametry in which tests upon the co-ordination of convergence and accommodation to the enhancement of ocular comfort and economy are made possible; the fact that static and dynamic results are not in agreement furnishes a basis for the determination of the proper assistance to be furnished in the interests of *all* the ocular functions concerned and enables the practitioner to inhibit excessive innervation, relieve weaknesses or to economi-

cally draw upon functions, which are in strength, to the relief of those which are in weakness through the medium of the lenses which he prescribes.

(2) Dynamic skiametric findings, taken at the reading point, indicate increased convex lens corrections as compared with the static retinoscopic findings and subjective acuity findings when esophoric, subnormal accommodative, or latent hyperopic conditions exist. Such findings also indicate the need of lens assistance in near work when convergence dissociation tests at thirteen inches show the existence of an over-convergence associated with accommodation in cases where no refractive errors or muscular imbalances exist at distance.

(3) The dynamic skiametric findings in myopia generally indicate lesser concave lens findings at the reading (thirteen inch) point than at twenty feet, because the deficiency in convergence, or exophoria, usually associated with myopia is supplied by the fusional convergence, since the decreased accommodative demands in such cases elicit a corresponding decrease in the convergence associated with accommodation. It is probable, therefore, in cases of myopia in which fixation and observation points are outside of the patient's far-point that dynamic skiametry will indicate findings in fair agreement with those which would statically result if the patient's far-point were to be left at the point at which observations are made. If such results accrue, it is evidence that full distance corrections should not be ordinarily prescribed for general use and especially for near work, since a too radical readjustment of the relations between accommodative convergence, fusional convergence and the

accommodation is not desirable. The history of the case, the symptoms of which complaint is made, the previous ocular corrections worn, or the absence of any previous refractive attention, must aid the practitioner in the judgments which he forms and prescriptions which he finally gives. In cases where the reserve fusional convergence is too heavily taxed, this deficiency in convergence may be supplied by additional accommodative convergence through an over-stimulation of accommodation, thereby indicating to the dynamic skiametrists as great, or greater, concave lens corrections at near as at distance. The demand for definiteness of fixation is met by increased accommodative convergence. Or, again, cases may arise in which greater degrees of myopia are indicated at the reading point as compared with the data furnished by the static findings, when conditions of functional exophoria, as detected at the reading point, and the total amplitude of accommodation available at this point indicate that less than one diopter of innervation accomplishes the act of one diopter of accommodation.

(4) The dynamic skiametric findings, in which hyperopic conditions are apparently found existent at near-points, while static methods evidence low-valued myopic conditions at distance demand careful investigation. Such findings are commonly found to exist in connection with spasms of accommodation and in cases in which there is an over-stimulation of the interni by virtue of the convergence associated with the innervation delivered in the interests of accommodation, indicating esophoric conditions at the reading point.

(5) All retinoscopic and subjective findings must be supplemented by tests upon the amplitude of ac-

commodation, the reserve convergence and investigations upon the convergence associated with the accommodation, while fusional convergence is passive, at the normal reading and near-work point. Such tests enable the practitioner to correctly diagnose his cases and analyze his findings and to know *why* and in the interests of *what functions* his final prescription is to be given.

(6) No single test is to be given preference over any other tests and none is to be assumed as giving an accurate finding; all data is to be taken and analyzed and from it all a logical conclusion drawn as to what should be prescribed in the interests of ocular economy and of the conservation of vision and all the functions therein involved.

In conclusion, we hope that a perusal of these pages may induce the reader to institute a systematic study of these most important ocular problems from the refractive standpoint. We hope that this compendium may serve to stimulate many to a reading of such standard works on ocular muscles as those by *Howe*, *Savage*, *Stevens* and others whose names and works are listed in the appended table, as well as to stimulate original investigations along these and similar lines.

NOTE. The writer will be pleased to furnish test cards corresponding to Figures 23, 25 and 28 to any who desire them.

REFERENCES.

Cross—Dynamic Skiametry in Theory and Practice.
Sheard—Dynamic Skiametry.

- American Encyclopedia of Ophthalmology.
Cross—Dynamic Skiametry in Theory and Practice.
DeZeng—The Modern Phorometer.
Donders—The Accommodation and Refraction of the
Eye.
Eberhardt—Dynamics and Economics of the Binocu-
lar Function. (Optical Journal).
Hansell and Reber—Ocular Muscles.
Howe—The Muscles of the Eye. Vols. I and II.
Javal—Manuel de Strabisme.
Landolt—The Refraction and Accommodation of the
Eye.
Laurance—Visual Optics.
Maddox—The Clinical Use of Prisms.
The Ocular Muscles.
Prentice—Ophthalmic Lenses.
Ophthalmic Lenses and Prisms. (Reprinted from
Vol X. of the American Encyclopedia of Ophthal-
mology.)
Savage—Ophthalmic Myology.
Ophthalmic Neuro—Myology.
Ocular Muscles. (Vol. X American Encyclopedia
of Ophthalmology.)
Sheard—Physiologic Optics (To be reprinted from
Am. Encyl. of Oph. when issued).
Dynamic Skiametry. (Keystone Magazine.)
Stevens—Motor Apparatus of the Eyes.
Thorington—Methods of Refraction.
Retinoscopy.
Tscherning—Physiologic Optics.
Valk—Strabismus or Squint.
Wiseman—Blood Pressure in Ocular Work.
Worth—Squint.

INDEX

A

Abduction, Tests for.....	47
Accommodative Convergence.....	43, 61
Clinical Methods of Testing.....	64
Accommodation, Spasm of.....	100
Objectively Determined.....	109
Relative, Measurement of.....	96
Acuity, Tests upon.....	36-41
Adduction, Tests for.....	47
Amplitude of Accommodation—	
Near-point Method.....	86
Concave Lenses at 20 ft.....	88
Concave Lenses at 13 inches.....	90
Inaccuracies in Near-point Method.....	86
Table of, by Various Authors.....	93
Apparent Near-point.....	109

II

Binocular Tests.....	49
Accommodative Tests, Objective.....	115-123
Blood Pressure in Ocular Work.....	10

C

Ciliary Relaxation.....	17
Clinical Methods of Testing—	
Accommodative Convergence.....	64
Binocular Accommodation.....	121
Relative Accommodation and Convergence.....	98
Relative Convergence.....	102
Reserve Convergence.....	64
Skiametry, Dynamic in.....	124-138
Comparison Tests—	
At Distance.....	33
At the Reading Point.....	36
Conclusions Relative to—	
Dynamic Skiametry.....	135
Ophthalmometry.....	32
Conditions Affecting Accommodative Convergence.....	62
Contrast, Immediate.....	33
Convergence—	
Accommodative.....	43, 61
Clinical Methods.....	64
Fusion.....	43, 58, 62, 74, 80
Fusional Dissociation.....	67
Relative, Measurement of.....	102
Table of.....	63
Tonic.....	59
Weak Positive (Case).....	83
Cross.....	124-128
Dynamic Skiametric Method.....	125
Skiascope.....	126
Cycloduction.....	48
Cyclophoria.....	15, 22, 70
Tests at near for.....	70
Cylinders for Distance and Reading.....	15, 23

D

DeZeng.....	47, 70
Donders.....	93, 95, 96, 97, 130
Rule Relative to Accommodation.....	96, 99
Dot and Line Test.....	65

Duction Tests—	
Oblique Muscles	48
Recti Muscles	45
Cases Illustrative of	54-57
Duane	93
Dynamic Far-point	117
Dynamic Skiametry	13, 14, 55
81, 82, 84, 101, 111, 112, 121, 122, 123, 124—	138
Cross Method	125
Author's Method and Interpretation	129

E

Eberhardt	19, 22, 26, 58
Equality of Acuity Tests	36-41
Essential Dynamic Tests	41-57
Exophoria, Physiologic	38, 58
Extrinsic Muscles, Essential Tests upon	41

F

Fixation, Necessity of Definite	17
Fusion Area	42, 46, 51, 52
Fusional Convergence	43, 58, 62, 74, 80
Fusional Dissociation—	
Lateral Tests upon	67

G

Gardiner , Ophthalmodynamometer	95, 96
Graefe , von	58, 65

H

History of a Case	8
Howe	38, 58, 95, 97, 99, 119
Method of Testing Acc. and Con	95, 96
Hyperphoria—	
Alternate Occlusion Test for	35
Tests at Near for	69
Hypophoria	35

I

Insertion of Binocular Findings in—	
Accommodative Tests	92
Acuity Tests	36
Muscle Tests	46
Irregular Refraction	18

J

Jackson	93
----------------------	----

L

Landolt	44, 54, 89, 97
On Convergence	44, 77
Laurance	26
Line and Arrow Test	72

M

Mascular Reflectoscope	19
Refraction	19-21
Maddox	38, 43, 51, 58, 59, 61, 63, 65, 74, 78, 120
Tangent scale	51, 73
Table of Convergences	63

Measurement, Binocular Objective Accommodation.....	115-123
Accommodative Amplitude	85-95
Cyclophoria	22, 70
Duction	45-48
Fusion Convergence.....	43, 58, 62, 74, 80
Monocular Obj. Acc.....	104-114
Relative Accommodation	96
Relative Convergence	102
Monocular, Objective Accommodation.....	104-114
Tonicity Tests.....	44, 51

N

Near-point Determinations	86
---------------------------------	----

O

Objective Monocular Accommodation.....	104-114
Binocular Accommodation.....	114-123
Oblique Muscles, Duction Tests of.....	47
Ophthalmometric Examination.....	11, 13
Conclusions Relative to.....	32
Illustrative Cases.....	12-16
Ophthalmoscopic Examination.....	10, 13
Optical Principles in—	
Objective Monocular Acc. Test.....	106-110
Binocular Accommodation Test.....	117-118
Orderliness, Necessity of.....	7
Outline of Eye Examination Routine.....	8

P

Periodic Squint	64
Hyperopia with	81
Peripheral Refraction	18
Phorometric Tests	42-54
Physiologic Exophoria	38, 58
Prentice Prism Rule.....	61, 68
Presbyopia	40, 113

R

Record Card	7
Reflectoscope, Macular	19
Refraction, Irregular and Peripheral.....	18
Retinal Sensitiveness as—	
Affecting Retinoscopic Findings.....	18
Retinoscopy, Scissors Movement in.....	23
Illustrative Cases.....	29-31
Recti Muscles—	
Tests upon Duction.....	45-47
Tests upon Tonicity.....	49-54
Routine of Eye Examination.....	8

S

Savage	16, 41, 45, 46, 52, 70, 74, 119
Scissor Movement in Retinoscopy.....	23
Conclusions Relative to.....	32
Illustrative Cases.....	29-31
Shift of Cylindrical Axes.....	14-16
Skiametry, Dynamic.....	13, 14, 55,
81, 82, 84, 101, 111, 112, 121, 122, 123, 124-138	
Cross Method	125
Author's Method and Interpretation	129
Squint, Periodic	64

Static Retinoscopic Tests.....	17
Steele Rules	16
Stevens.....	38, 52, 54
Stevenson Muscle Test.....	51, 58, 73

T

Test Object for—	
Accommodative Convergence.....	66, 72
Esophoria and Exophoria.....	66, 72
Fusion Convergence	76
Monocular Objective Accommodation.....	105
Theobald	58
Thorington.....	25, 26, 28
Tonic Convergence	59
Tonicity Tests	44
Tonicity Tests on Recti Muscles—	
Binocular Tests	49
Monocular Tests	52
Treatment of Muscular Imbalances.....	79

V

Version Tests	54
---------------------	----

W

Weak Positive Convergence.....	83
Wiseman	10
Worth.....	38, 58, 65



WW 300 S539d 1917

52310640R



NLM 05274016 8

NATIONAL LIBRARY OF MEDICINE